MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA .

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MADRAS

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MINERAL RESOURCES OF MADRAS

BY

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PREFACE

The information presented in this monograph has been gathered together from various publications, supplemented by the recent work of the Geological Survey of India. A party of the Survey was assigned to the Madras Province from 1939-40 and stationed at Madras from 1942 under the supervision of the present writer. The number of officers in this (Southern) Circle was 3 in 1940 and has grown to 17 or 18 in 1948, but, owing to the current heavy demand for trained geologists all over the country, about half the strength of the party has consisted of new and inexperienced officers under training. It is hoped that this will be rectified soon, as more trained officers become available.

An appreciable amount of useful work has been accomplished during the last few years, especially in the investigation of mineral deposits. The pace of these investigations can be accelerated by the provision of better facilities for prospecting, including the use of geophysical methods.

For the complete understanding of mineral deposits it is necessary to do systematic mapping of the area and study their geological relationships. Such systematic mapping has recently been started in several districts—Tinnevelly, Trichinopoly, Salem, Guntur, Kurnool, West and East Godavari—and will be continued in future. It will bring to light the existence of all mineral deposits of any importance.

The mineral statistics presented in the paper are not very satisfactory and reflect the defective nature of the organisation at present employed in collecting them. Minerals are classified as 'major' and 'minor' and some mines come under the Mines Act and others don't. It is only for the major minerals which are recovered from mines coming under the Act that reasonably reliably statistics are available. The others are largely inaccurate. Generally information is not available regarding grades and qualities; the destination and uses to which they are put ; the facilities available for processing and the amounts processed before shipment, etc. A province-wide and country-wide reconstitution of the agency now employed and the methods adopted by them for collecting statistics is urgently needed, if we are to make our statistics reliable and base our plans of mineral development on them.

At present licences and leases for prospecting and mining are granted by the Collectors of Districts under the supervision of the Board of Revenue. A clerk in the Collectorate is virtually the mineral expert and only rarely is the advice of the Geological Survey sought. Thus, mining leases are regarded primarily as land revenue propositions and not as propositions in which mineral wealth and mining technique are involved. This unsatisfactory state of things can be set right only if all mining matters are dealt with by a central office attached, say, to the Director of Industries and managed by people trained in geology and mining. The adoption of this suggestion will help to bring uniformity in conditions of leasing throughout the Province and also bring about better administration of mineral matters and collaboration with other Provinces in mineral policies. Incidentally, such an organisation can also be made responsible for the collection and publication of the provincial mineral statistics.

In this compilation done in 1946-48, the writer has used not only information published in journals and official publications, but also the unpublished reports of his colleagues who have worked in the Southern Circle of the Geological Survey of India since it was constituted—in particular Dr. B. C. Roy, Mr. N. K. N. Aiyengar, Mr. M. S. Venkatram, Dr. K. Jacob, Mr. M. S. Balasundaram, Mr. V. Subramanyam, Mr. S. Narayanaswami, Mr. A. P. Subramaniam, Mr. R. Thiagarajan and Mr. S. N. Sen. The majority of the recent reports relating to the Madras Province have been published at various times in the Fort St. George Gazette as G.O.'s of the Development Department, to which references are given in the relevant places in the text. These and other published references appended under each section may be consulted by those interested, for fuller information.

CONTENTS

	Pages
Chapter I.—Physical Features and Geology	1—15
A. Physical Features	1—5
Mountains	2—3
Climate	3—4
Rainfall	4
Rivers	4—5
Lakes	5
B. Structure	5—6
C. Geology	6—12
D. Distribution of Minerals	12—15
Chapter II.—Abrasives	16—21
Chapter III.—Antimony	22
Chapter IV.—Aluminium Sulphate	23
Chapter V.—Asbestos	24—28
Chapter VI.—Barite	28—34
Chapter VII.—Bauxite	35—36
Chapter VIII.—Building Stones	37—40
Chapter IX.—Chromite	41—47
Chapter X.—Clay	48—69
Chapter XI.—Coal	70—76
Chapter XII.—Columbite-Tantalite	77—79
Chapter XIII.—Copper	80—88
Chapter XIV.—Cordierite	89—90
Chapter XV.—Corundum	91—98
Chapter XVI.—Diamonds	99—105
Chapter XVII.—Feldspar	106—109
Chapter XVIII.—Fluorspar	110—111
Chapter XIX.—Garnet	112—114
Chapter XX.—Gemstones	115—119
Agate and Chalcedony	115
Apatite	115
Beryl	116
Chrysoberyl	116
Cordierite (Iolite)	116
Corundum	116
Diamond	117
Feldspar	117
Garnet	117
Kyanite	118
Quartz	118
Opal	118
Serpentine	119
Tourmaline	119
Zircon	119

	PAGES.
CHAPTER XXI.—GOLD	120—129
CHAPTER XXII.—GRAPHITE	130—133
CHAPTER XXIII.—GYPSUM	134—137
CHAPTER XXIV.—IRON	138—153
Steel making in former times	138
Attempts at conducting a modern industry	139
Previous work	140
CHAPTER XXV.—KYANITE AND SILLIMANITE	154—156
CHAPTER XXVI.—LEAD	157—160
CHAPTER XXVII.—LIGNITE AND PEAT	161—171
Peat	161—162
Lignite	162—171
CHAPTER XXVIII.—LIMESTONE AND DOLOMITE	172—197
CHAPTER XXIX.—MAGNESITE	198—207
CHAPTER XXX.—MAGNETITE	208
CHAPTER XXXI.—MANGANESE	209—219
CHAPTER XXXII.—MICA	220—240
CHAPTER XXXIII.—MINERAL PIGMENTS	241—247
CHAPTER XXXIV.—MOLYBDENUM	248—249
CHAPTER XXXV.—NATURAL GAS	250—251
CHAPTER XXXVI.—PHOSPHATES	252—257
CHAPTER XXXVII.—QUARTZ AND SILICA	258—259
CHAPTER XXXVIII.—REFRACTORIES	260—262
CHAPTER XXXIX.—ROAD STONES AND AGGREGATES	263—264
Physical Properties	263
Petrographic Characters	264
CHAPTER XL.—SANDS	265—266
Foundry sand	265
Glass sand	265
Sands for other uses	265
CHAPTER XLI.—SODA AND POTASH SALTS	267—268
CHAPTER XLII.—SLATE	269—271

PAGES

CHAPTER XLIII.—STEATITE AND TALC . . . . 272—275

CHAPTER XLIV.—STRONTIUM . . . . 276—277

CHAPTER XLV.—SULPHUR AND PYRITES . . . . . . 278—282

Native Sulphur 279

Pyrite 280

Pyrrhotite . . . . 280—281

CHAPTER XLVI.—TITANIUM . . . . 283—287

Rutile 283

Ilmenite 284

CHAPTER XLVII.—WATER SUPPLY . . . . 288—290

Artesian Springs 289

CHAPTER XLVIII.—ZIRCON . . . . 291—292

OUTPUT AND VALUE OF MINERALS PRODUCED IN MADRAS . . . 293—299

Index 300

PLATES

PLATE 1.—Iron ores of Salem and Trichinopoly districts.

PLATE 2.—Deposits of limestone in Salem district.

PLATE 3.—Crystalline limestones in Tinnevelly district.

PLATE 4.—Crystalline limestones in Ramnad-Tinnevelly districts.

PLATE 5.—Magnesite area, Chalk Hills, Salem district.

PLATE 6.—Map showing occurrences of celestite in the Trichinopoly district.

PLATE 7.—Map showing occurrences of phosphatic nodules in the Trichinopoly district.

PLATE 8.—Map showing gypsum occurrences in the Trichinopoly district.

PLATE 9.—Map of Lingala coalfield.

PLATE 10.—Gaviridevipeta coalfield.

PLATE 11.—Neyveli lignite field, South Arcot district, showing location of bore-holes.

PLATE 12.—Mineral Map of Madras.

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MINERAL RESOURCES OF MADRAS, by M. S. KRISHNAN, Ph. D., F. N. I., *Director, Geological Survey of India* (with Plates 1 to 12)

CHAPTER I.

PHYSICAL FEATURES AND GEOLOGY.

A.—Physical Features

Before the establishment of an official Geological Survey of India a fair amount of information was gathered on the minerals occurring in the Province of Madras by some enthusiastic professional and amateur geologists in the service of the East India Company. Prominent amongst these were Heyne, Voysey, Muzzy, Newbold and Balfour, while some travellers who had interest in matters geological, like Tavernier, Count de Bournon, Leschenault de la Tour and Francis Buchanan-Hamilton, have also contributed to this knowledge in some measure by recording the information which came to their cognisance.

Systematic work on the geology and mineral resources of India may be said to have begun with the arrival of Dr. T. Oldham in 1851 as Superintendent of the Geological Survey of India though there were official geologists before him. Madras received early attention from this official organisation and much of its area was covered before the year 1890. The pioneers whose contributions have enriched our knowledge are C. Æ. Oldham, H. F. Blanford, W. T. Blanford, William King, R. Bruce Foote, Philip Lake, (Sir) T. H. Holland, C. S. Middlemiss and T. L. Walker. As a result of their labours we have a general geological map and a good deal of information on mineral deposits. This information, however, lacks detail in most cases, since the early work was not followed up by detailed investigation at a later date.

Systematic re-mapping and investigation suited to modern needs have recently been commenced in this Province. The available information has been brought together and is presented here so that it may be useful to all interested in minerals and as a basis for further work.

The Province of Madras forms the southernmost part of Peninsular India, lying roughly between North Latitudes 8° and 19° and East Longitudes 74½° and 84° bounded on the east and west by the sea. It encloses partially or wholly the larger States of Mysore, Travancore and Cochin, and is bounded on the north by the territories of the Bombay Presidency, Hyderabad State, Eastern States Agency and Orissa.

The Province has a total area of 133,893 sq. miles and is divided into 25 administrative districts which are enumerated below :—

District.	Area (sq. miles).
Vizagapatam	8482
East Godavari	6220
West Godavari	2361
Kistna	3547
Guntur	5757
Nellore	7949
Cuddapah	5919
Anantapur	6741
Bellary	5713
Kurnool	7581
Chittoor	5091
Chingleput	3091
Madras	29
North Arcot	4648
South Arcot	4208
Tanjore	3742
Trichinopoly	4314
Salem	7058
Coimbatore	7085
Nilgiri	982
Malabar	5794
South Kanara	4021
Madura	4912
Ramnad	4819
Tinnevelly	4315

The boundaries between districts are often physical barriers like hill ranges or rivers so that they are, as a rule, very irregular and sinuous in configuration.

MOUNTAINS

Practically all the mountains in this Province can be considered to form part of either the Eastern Ghats or Western Ghats which are mere geographical entities and do not possess structural or stratigraphical unity.

The Western Ghats are geographically and topographically continuous from Nagercoil near Cape Comorin through the Nilgiris and the western border of Mysore to the southern districts of the Bombay Province. They consist mainly of charnockites and gneisses but in Mysore they include also strips of the Dharwarian formations. Branching off from them in the south are the Anaimalais, Palni Hills, Cardamom Hills and Varshanad Hills which are rugged hill

masses containing much charnockite. The Western Ghats form the main watershed of the Peninsula since all the important rivers rise on them and flow eastwards, and there are numerous streams flowing westwards into the Arabian sea. The Eastern Ghats consist of distinct units which are only roughly continuous in a geographical sense. They comprise the Ghats of the Northern Circars composed of charnockites and khondalities, the quartzite and shale ridges of the border of Nellore and Cuddapah districts (forming the Velikondas, Nallamalais and Palkondas), and the hills of charnockites and Dharwarian rocks in Arcot and Salem (the Javadi Hills, Kalrayan Hills, Shevaroys, etc.), continuing into the southern border of the Mysore plateau and the Nilgiris.

The Eastern and Western Ghats may be considered to meet in the mountain knot of the Nilgiris whose highest peak, Dodabetta, rises to an altitude of 8,640 feet. The Western Ghats have a strike more or less parallel to the Coast north of the Nilgiris but further south they strike N.W.—S.E. In the angle between the Western and Eastern Ghats lies the Mysore plateau having an average elevation of 2,500 feet above the sea level. This plateau leads, to the north and north-east, into the Cuddapah basin of sedimentary rocks which is intermediate in altitude between the plateau and the coastal plains.

The coastal plain in the east is about 30 miles wide in the Northern Circars, becoming somewhat broader in Guntur and Nellore. South of Madras, the hills recede further and the plains are 50 miles or more wide. The coastal tract to the west of the Western Ghats is much narrower and averages 10 miles in width. This coast is characterised by lagoons or backwaters (known as Kayals in Malayalam) which serve as waterways especially in Malabar, Cochin and Travancore.

CLIMATE

The climate of the Province is of the tropical monsoon type. The western Coast is much more humid than the eastern, while the central parts are comparatively dry. The plains have an equable temperature all the year round with a small range, 75° F. to 105° F., while the central districts may show a maximum summer temperature of 115° F. (rarely 120° F.). The rainy months are from the latter part of May to October (South-west monsoon), and from November to January (North-east monsoon). Summer begins with March, the highest temperatures being recorded in the latter part of April and the earlier part of May. With the onset of the south-west monsoon, the temperature is lowered even in the eastern districts as the humid winds blow over them without, however, precipitating any moisture. It is only in the central districts that

a mild winter is felt in December and January, the coastal tracts experiencing merely a small general drop in temperature which makes an agreeable change from the hot summer.

RAINFALL

The rainfall varies considerably in different parts of the Province. The south-west monsoon brings rain to the western coast during the months of June to September but there is also some rain in the other months. The total rainfall in the region to the west of the crest of the Western Ghats is of the order of 100 inches per annum. An appreciable precipitation also occurs in the higher hills to the east of the Western Ghats—e.g., Palnis, Shevaroys, Kalroyans—during the south-west monsoon season. The eastern plains, on the other hand, receive most of their rain during October and November, the retreating period of the south-west monsoon, and also a little in the cold months when the north-east monsoon is active. These plains receive 20 to 40 inches of rain per annum. It is least in the dry belt passing through Salem and parts of the Ceded districts into western Hyderabad and Central India. This is the region of frequent famines, not because the rainfall (20-25 inches) is insufficient, but because it is in some years untimely with reference to the crops.

RIVERS

There are numerous rivers in this Province but only a few are of some magnitude. These are: the Godavari, Kistna, Penner, Ponnaiyar, Cauvery, Vaigai and Tambraparni. All these rise either in the Western Ghats or on the border of the Mysore Plateau, flow initially through rugged country and then over the flat coastal plain before emptying themselves into the Bay of Bengal. There are usually some waterfalls or Cascades in the upper courses while the middle courses are marked by good gradients and rocky beds. On debouching into the plains they become sluggish and begin to deposit their load of sediment. Only the larger rivers like the Godavari, Kistna and the Cauvery have built up good deltas which are the most important rice-producing areas in the Province.

The river systems and their history have not been studied in any great detail. A detailed study will lead to the discovery of much interesting information. It is known, for instance, that the present Palar was an unimportant stream in geologically recent times and that the old Palar flowed through what is now the basin of the Kuvam (Cooum) and Kortalaiyar and entered the sea near Ennore north of Madras. There is evidence that the course of the Godavari near Polavaram (some 20 miles above Rajahmundry) lies in over a drowned gorge the bottom of which is 180 feet below the present river bed.

It is seen that, as a general rule, the rivers have a N.N.W. to S.S.E. course especially in their lower portions. This does not correspond to the general strike of the rocks except in the southernmost districts south of the Nilgiris. But this may be attributed to a tilt which the Peninsula is supposed to have received when the portion lying to the west of the Western Ghats was faulted down and drowned under the Arabian sea probably during the Miocene times. There is some evidence that in the late Pleistocene or sub-Recent times the Coast was subjected to a slight downward movement.

The predominant northward drift or current along the Coast for the greater part of the year has the effect of giving a slight northerly turn to the rivers where they enter the sea. The deposition of the sediments carried by the rivers will be influenced by this drift while bars grow across the mouths from the south to north. This current has also the effect of forming a beach just to the south, and of eroding the Coast just to the north, of any natural or artificial obstruction such as the Madras harbour and the Dolphin's nose at Vizagapatam.

LAKES

There are no important lakes in the interior of the Province but there are a few near the Coast. The back-waters (*kayals*) on the Malabar and Travancore Coasts, the Kaliveli tank north of Pondicherry, the Pulicat lake north of Madras, the Colair (or Kolleru) near Ellore are fairly large expanses of water. In addition there are numerous ponds and small lakes in several districts, e.g., Tinnevelly, Ramnad, South Arcot, Chingleput, which are mostly due to obstructed drainage and are used for irrigation purposes.

B.—**Structure**

The Madras Province presents a variety of geological formations, though the geological record is far from complete and the sedimentary formations are comparatively poorly developed.

The major structures are seen delineated in the Archaean rocks. The Dharwarian rocks of Mysore and Nellore show a N.N.W.—S.S.E. strike which occasionally changes to a N.—S. direction. In the Eastern Ghats in the Circars the strike is N.E.—S.W., parallel to the general trend of the hills. In the Nellore—Guntur region it becomes nearly N.—S. but further to the south-west in the Arcot and Salem districts, the direction is anything between N.—S. and E.N.E.—W.S.W. South of the Nilgiris Mountains, the prevailing direction is N.W.—S.E. which is characteristic of the rocks of Madura, Tinnevelly and Travancore. These strikes are continued in the appropriate parts of the island of Ceylon.

The Cuddapah basin, composed of ancient sedimentary rocks has also been affected by the earth movements of post-Archaean age. It occupies parts of the districts of Cuddapah, Kurnool, Anantapur and Chittoor and its eastern margin is part of the Eastern Ghats in Guntur and Nellore and follows the earlier structural lines.

The Gondwana formations found in the Godavari valley are located in faulted tracts. The Upper Gondwanas which are found in the plains of West Godavari, Guntur and Chingleput are estuarine or shallow water deposits. They are followed by Cretaceous and Tertiary strata which are developed in the coastal tracts. These indicate the occurrence of marine transgressions of some magnitude.

The extraordinary straightness of the western coast (especially its continental shelf) is cited as proof of its being a fault line. It is certainly post-Deccan Trap and probably Miocene in age since the earliest marine beds found on the western coast below Bombay are of Miocene age. The eastern coast, however, is older and dates probably from the Upper Gondwana times.

Ceylon is separated from India by a very shallow stretch of water (Gulf of Manaar and Palk Strait). The date of separation is probably the time when the Cuddalore sandstones and Jaffna beds were formed, i.e., Miocene to Pilocene.

There are three main peneplains in this part of India, the lowest being the coastal plain, the middle one comprising the Mysore plateau and the lower ridges and hills, and the upper one the Nilgiri uplands. Dr. D. N. Wadia has suggested that these are post-Upper Gondwana and that the upper two peneplains are due to block faulting whereby they have been left as horsts; according to him the abrupt descent from the upper to the middle peneplain and certain other features are best explained by this hypothesis.

C.—Geology

The Archaean Group.—The greater part of the Province is occupied by a complex group of gneisses and schists of Archean age. They include both sedimentary and igneous materials which have been highly metamorphosed and invaded by various igneous intrusives. They comprise different types of schists—micaceous, hornblendic, chloritic, talcose, etc., and gneisses which may be massive or banded. Where the grade of metamorphism is high, as in parts of Salem the resultant rocks are granulitic in character and contain garnet, staurolite, sillimanite, etc., while the calcareous rocks are calc-gneisses and calc-granulites. The igneous types are represented by amphibolites, epidiorites, garnetiferous gneisses, pyroxene granulites and others. The more schistose types are classed under the Dharwarian system. They form a series of highly folded and

sheared strips found typically in parts of Mysore and in several districts of Madras. They are probably older than parts of the gneisses with which they are associated and certainly include some of the oldest sediments we are cognisant of. They include also important beds of ferruginous quartzites or jaspers and manganese ores. The Archaeans (Dharwars and associated gneisses and igneous rocks) have been subdivided as follows in Mysore State where they have been studied in some detail :—

	Basic dykes	
	Felsite and porphyry dykes.	
	Closepet granite	
	Charnockites	
	Basic dykes	
	Peninsular gneiss	
Dharwar System	Upper Dharwars . .	Ferruginous, cherty, calcareous silts, etc.
	Middle Dharwars . .	Ironstones, limestones, argillites, quartzites, etc.; ashes and tuffs.
	Lower Dharwars . .	Rhyolites, felsites, quartz porphyry, etc. Basic volcanics.
		Base not recognised.

The Dharwarian system appears to rest on gneisses but there is little doubt that the contact is not one of original deposition. Indeed, the earlier members of the Dharwars contain much igneous material which has been metamorphosed.

Ferruginous quartzites and iron ores are found mainly in the middle division as also in the upper division.

Much the larger part of gneisses in South India belong to the division called the Peninsular gneiss group, consisting of granitic and granodioritic gneisses including banded and composite varieties and highly granitised schists.

In the Kolar schist belt there is a sheared micaceous gneiss characterised by the presence of opalescent quartz, called the Champion gneiss, which is older than the Peninsular gneiss. But the presence of the opalescent quartz is not a unique criterion since it occurs also in some other types which are younger. Younger than the Peninsular gneisses are the charnockites which are a group of rocks with igneous characteristics, varying in composition from acid to ultra-basic and characterised by the rhombic pyroxene, hypersthene. The quartz (present in acid and intermediate varieties)

is bluish grey in colour and contains acicular inclusions of rutile. Perthitic microcline and plagioclase are common while orthoclase is less so. Augite and rarely hornblende are found in addition to hypersthene. Garnet is common in some varieties. The basic types include pyroxenites and hypersthenites. The charnockites are widely distributed in South India and Ceylon, particularly in the Eastern Ghats, Shevaroys, Nilgiris and the mountains further south. Their characters are now regarded as due to metamorphism under deep-seated conditions.

The Closepet granites are pink or grey biotite-granites including porphyritic varieties. They contain inclusions of older rocks and are traversed by dykes and lenses of felsites and porphyries. Similar granites have been described from other places under the names of Bellary gneiss, Hosur gneiss, Balaghat gneiss, etc.

A few other types of rocks are also found in the Archaeans. The **Khondalites,** typically developed in the Eastern Ghats, are garnetiferous quartz gneisses with sillimanite and graphite and occasionally some feldspar; they are considered to be para-schists derived from argillaceous sediments. The **Kodurites** are manganiferous hybrid rocks consisting or orthoclase, manganese-garnet (spessartite-andradite) manganese-pyroxene and apatite found in association with the manganese bearing rocks of Vizagapatam. **Ultrabasic rocks** such as dunites and peridotites are found in Salem; they have been altered to some extent, giving rise to workable deposits of magnesite. **Alkali-syenites** (elaeolite-syenites) are developed in the Vizagapatam and Coimbatore districts, the latter occurrences being associated with augite syenites and feldspar-corundum rocks. Anorthosites with corundum and amphibolites and pyroxenites with chromite are found in Salem. Amongst the latest rocks intrusive into the Archaean schists are the mica-bearing pegmatites found in several places in the Nellore, Nilgiri, Salem and other districts. These pegmatites are undisturbed by any earth movements and are therefore post-Archaean. There are some basic dykes traversing the Archaean schists and granitic rocks. They are also unaffeted by earth movements and therefore thought to be post-Archaean (or Cuddapah) in age.

Then intervened a period of uplift and denudation followed by submergence of parts of the Peninsula when the Cuddapah formations were laid down. These form the Cuddapah basin and occupy parts of Guntur, Nellore, Chittoor, Cuddapah, Kurnool and Anantapur districts. The outcrops have the form of a crescent whose

eastern margin is concave. The Cuddapahs are disturbed, but less than Archaeans, and the rocks are also less metamorphosed. They are divided into four series, as below :—

Kurnool System.

Cuddapah System	Kistna Series . . .	Srisailam quartzites. Kolamnala shales. Irlakonda quartzites.
	Nallamalai Series . .	Cumbum shales. Bairenkonda quartzites.
	Cheyair Series . .	Tadpatri (Pullampet) shales. Pulivendla (Nagari) quartzites.
	Papaghni Series . .	Vempalle shales and limestones. Gulcheru quartzites.

Archaeans.

The Gulcheru quartzites form prominent scarps on the outer borders of the basin and include also some grits and conglomerates. The vempalle limestones are mainly dolomitic and contain numerous deposits of barytes and a few of chrysotile asbestos, the latter being developed at the zone of contact with trap sills traversing the limestones. The Pulivendla quartzites contain some jasper conglomerates and ripple-marked quartzitic sandstones near Lingala a few miles west of Pulivendla in Cuddapah. The Tadpatri shales (also known as Pullampet shales) cover a large area north of Pulivendla where they are shaly in character. The Cumbum shales are for the most part slaty and contain good slates near Cumbum and Markapur on the borders of the Kurnool and Nellore districts. The uppermost series is developed in the northern parts of the basin in the Kistna valley and include quartzites, shales and slates.

The Cuddapah System is followed by the Kurnool System which is also developed in the same basin and comprises four series as shown below :—

Kundair Series . .	Nandyal shales. Koilkuntla limestones.
Paniam Series . . .	Pinnacled quartzites. Plateau quartzites.
Jammalamadugu Series .	Auk shales. Narji limestones
Banganapalle Series .	Banganapalle sandstones.

The Banganapallis are coarse sandstones containing pebbles of slate, quartz, jaspar, etc., derived from the earlier formations. They have yielded diamonds. The Narji limestones are good limestones useful for building and decoration. The 'Cuddapah slabs' which are flaggy calcareous slates quarried near Jammalamadugu, Betamcherla and other places are referable to the Auk Shales stage. The Kundair series contains limestones as well as shales especially in the Kundair valley.

The Kurnool System is correlated with the lower part of the Vindhyan System of Northern India. It is also affected to some extent by earth movements which have induced a low grade of metamorphism of the rocks such as the conversion of sandstones into quartzites and shales into slates.

The Cuddapahs and Kurnools were raised up and compressed by earth movements. A considerable period elapsed before the Peninsula experienced any sedimentation. The succeeding formations belong to the coal-bearing Gondwana System developed along the Godavari valley and some parts of the eastern Coast.

The Lower Gondwanas comprise two divisions, a lower one called the Barakar stage and a upper one called the Chintalpudi (Kamthi) stage. The Barakars consist of grey to drab sandstones, sometimes felspathic, and shales. The sandstones and shales are carbonaceous and may contain streaks, layers and seams of coal. Three or four patches of Barakars are exposed in the Godavari Agency tracts on either side of the river.

The Chintalpudi sandstones are medium to coarse, somewhat ferruginous, red to brown sandstones occupying a fairly large tract from near Ashwaraopeta on the Hyderabad border (West Godavari) to Chintalpudi near Ellore and Gopalapuram north of Kovvur. They overlie the Barakars with a very low or undulating dip. So far as known, the cover of Chintalpudi Sandstones is only a few hundred feet thick over a large part of the exposure.

Still further east, the Chintalpudi Sandstones are overlain by the Upper Gondwanas, consisting of three divisions, *viz.*, the Golapilli sandstones, Raghavapuram shales and Tripetty (Tirupati) sandstones occupying a comparatively narrow tract passing through Gopalapuram and Dwaraka Tirumala in West Godavari district. These divisions contain plant fossils as well as lamellibranch and gastropod remains.

The Upper Gondwanas are developed in the Ongole area in the Guntur district where three similar divisions are recognised; in the Chingleput district some 25 miles west of Madras and near Uttattur in the Perambalur taluk of the Trichinopoly district. Similar formations are also said to exist near Sivaganga in the Ramnad

district. The correlation of these rocks in the different areas is shown below :—

Age	Ellore (W. Godavari)	Ongole (Guntur)	Near Madras	Trichinopoly
Chikiala . .	Tirupati sandstone	Pavalur sandstone	Satyavedu sandstone.	—
Kota . .	Raghavapuram shale.	Vemavaram shale	Sriperumbudur shales.	Uttatur plant beds.
Rajmahal . .	Golapilli sandstone	Budavada sandstone.	—	—

From the presence of ammonites in those beds the opinion has been expressed that they are of Lower Cretaceous age, in part.

In the Uttattur area the Upper Gondwana rocks are succeeded, with an unconformity, by Cretaceous rocks. They are developed in the Uttattur-Ariyalur, Vriddhachalam and Pondicherry areas. They extend in age from the Cenomanian (or uppermost Albian) to the Danian and perhaps continue into the Eocene in the Pondicherry area. Three stages are recognised, named respectively (from below upwards) Uttattur, Trichinopoly and Ariyalur stages. All contain abundant fossils, especially cephalopods, lamellibranchs and gastropods. The strata are clays, sands and local banks of limestone. Some fossil wood is found, particularly in the Trichinopoly Stage. The clays of the Uttattur Stage are traversed by veins of gypsum, celestite, calcite and chalk, and contain nodules of impure calcium phosphate and calcium carbonate.

Only the Ariyalur Stage is developed in the Vriddhachalam and the Pondicherry areas, the three areas being separated from each other by the alluvia of the Vellar and the Ponnaiyar.

The Cretaceous rocks are succeeded by Tertiary sandstones and clays in the Trichinopoly, South Arcot and Tanjore districts. Similar deposits found in a few other Coastal districts go under the names of Cuddalore sandstones, Rajamahendri Sandstones and Warkalli (Varkala) beds. They are regarded as of Miocene age. Somewhat younger beds have been met with at a depth of about 350 feet at Karikal in the Tanjore district. Of about the same age are the Jaffna beds in Ceylon. The Tertiary rocks contain some good deposits of limestone and clay and also some lignite in places. They are often capped by laterite.

The Pleistocene and Recent deposits include Older and Newer alluvia in several of the river valleys and deltas, and certain deposits along the Coast like the calcareous sandstones on the Tinnevelley Coast. Some coral limestones are also forming in parts of the Gulf of Manar.

The Peninsula has apparently undergone vertical movements several times since the Archaean era. There have been important compressive movements in the post-Archaean, post-Cuddapah and post-Vindhyan times. Since then, however, the movements have generally resulted from tension. Some oscillatory movements must have occurred during the Gondwana period as these rocks show alternations of sands and clays with occasional carbonaceous matter in the Barakar strata. An uplift certainly took place after the Upper Gondwanas were deposited, as they are followed uncomfortably by the Cenomanian strata in the Trichinopoly district. The sea transgressed in Cenomanian period and then again in the Miocene, and deposited the rocks which we now refer to these ages. The Cuddalore sandstones are presumably conformably overlain by the Karikal beds in the Tanjore district, the former of these having a very gentle seaward dip. The severance of Ceylon from India is probably to be referred to the period of the commencement of deposition of the Cuddalore sandstones. There were some uplifts and depressions during the Pliocene and the Pleistocene, when Ceylon was united to and severed from India.

There appears to be some evidence of a slight submergence of the Coast during the late Pleistocene or Sub-Recent period. Parts of the deltas of the larger rivers and the older alluvia must have been formed during the Pleistocene and the sub-Recent times. As evidence of submergence may be cited the following: San Thome near Madras is said to have lain "twelve leagues inland from the sea" though this is apparently an exaggeration. It is recorded that near the Coast at Mahabalipuram an old road was discovered some 6 or 7 feet below the present one, indicating some submergence. The sea is known to have encroached on Tranquebar as mentioned by Oldham. The famous port of Kaverippumpatnam which was a flourishing port in the days of the Chola Kings is said to be now buried several feet below the present ground level. There is evidence from recent bore-hole records that the Godavari now flows near Polavaram over a buried gorge whose rocky base lies some 180 feet below the present river bed (and some 120 feet below sea level), the gorge having been filled up by sands and pebble beds. A drowned forest is known in the Valinokkam bay on the Tinnevelly Coast while peat beds are said to exist near Point Calimere on the Tanjore Coast. The downward movement may be the reason why there is little or no evidence of delta formation at the mouths of the smaller rivers.

D.—Distribution of Minerals

Mineral deposits are related in some measure to the nature and composition of the rocks in which they occur and also to certain

geological structures. In some cases, certain minerals are exclusively characteristic of certain rock types—e.g., chromite in ultrabasic rocks. The minerals found in the chief geological formations are mentioned below :—

Archaeans.—The schistose part of the Archaeans, usually known as the Dharwarian System, is the richest mineral bearing group of all. This system carries iron and manganese ores as bedded deposits and copper ores as veins. Quartzites, micaceous and chlorite schists and crystalline limestones are useful rock types found in them. Amongst the minerals found in them are graphite, pyrite, pyrrhotite. apatite, barite, kyanite, sillimantite, corundum, garnet and a few others.

The igneous rocks in the Archaeans also enclose certain useful deposits. The granites and pegmatites are the home of quartz, feldspar, mica, beryl, samarskite, tantalite, etc. Gold is usually associated with vein quartz and pyrites. Alteration of feldspathic rocks (mainly pegmatite or granitic rock) gives rise to kaolin. With the basic and ultrabasic rocks are associated steatite, asbestos, magnesite, chromite, corundum, phlogopite mica.

The gneisses, charnockites, granites, the bedded schistose quartzites and crystalline limestones are useful for building purposes. Some of these are stones of high ornamental value.

Cuddapah and Kurnool Systems.—Some of the rocks of these systems are good building stones—quartzites, limestones, dolomites, slates, sandstones. Special mention may be made of the slates from the 'Cumbum Slates' worked near Markapur, the Narji limestones and marbles worked in the Palnad area of Guntur and the Cuddapah slabs of the Jammalamadugu and Kundair formations in the Cuddapah and Kurnool districts.

Barite, asbestos and steatite are amongst the most important deposits found in these. There are also some veins of lead ores in the Cuddapah and Kurnool districts. Some ferruginous quartzites near Cuddapah have given rise locally to deposits of hematite while the fault zone passing close to Ramallakota contains fair sized deposits of good hematite (specular ore). Various types of clays and red and yellow ochres are also available and are actually being mined.

Gondwana System.—The Gondwana formations contain coal, sandstone and different types of clays. No workable coal seams have been found within this Province though, just across the border in Hyderabad, coal seams are being worked at Singareni and Kothagudem. Good white and light buff ceramic clays have been won from West Godavari and Chingleput districts.

Cretaceous System.—The Cretaceous formations in the Trichinopoly and South Arcot districts contain limestones and clays, some of the former being shell limestones useful as ornamental stones. In the Trichinopoly district these formations contain veins of gypsum, celestite (some barite), calcite, chalk and nodules of calcium phosphate. Of these only the gypsum is worked now-a-days regularly.

Tertiary Group.—The Tertiaries are composed of sandstones and clays, the former containing pockets of red and yellow ochre while the latter yield refractory and ceramic clays which are worked in the South Arcot district. These formations are generally capped by laterite which is a popular building stone. The Cuddalore sandstones of South Arcot and similar strata in Malabar contain some lignite which may be workable.

Quaternary Formations.—The Pleistocene and recent formations which include the alluvium, soils and coastal sands, yield good brick clays and sands for building and other purposes. The Coastal sands (mainly silica) of Ennore near Madras have been used at Madras for glass making. Other sands found on the Tinnevelly, Travancore and Malabar Coasts contain ilmenite, monazite, zircon, garnet, rutile and other minerals, some of which are worked and concentrated for export.

In certain areas there are efflorescences of alkali salts in these formations, especially sodium sulphate, sodium carbonate and sodium chloride. Nitre is also found in a few places marked by dense human population and cattle.

Summarising this information, we can show below the minerals found in the various geological formations.

Archaean.—Ores of Iron, manganese, gold, copper (possibly lead and zinc), chromium, molybdenum; mica, beryl, chrysoberyl, samarskite, columbite-tantalite, monazite, feldspar, quartz; magnesite, asbestos, talc, kyanite, sillimanite, garnet, corundum, apatite, graphite, pyrite and pyrrhotite, barytes, calcite, dolomite; a large variety of building stones including granite, gneiss, charnockite, quartzite, quartz and mica schists, limestones and marble.

Cuddapahs and Kurnools.—Ores of lead and zinc; hematite; diamonds; barytes, asbestos, ochres, steatite, clays. The building stones include limestone, marble, sandstone, quartzite, slate, 'Cuddapah slabs' (calcareous slaty flags), serpentine.

Gondwanas.—Coal, fire-clay and other clays, sandstone, some ochre.

Cretaceous.—Gypsum, celestite (some barytes), calcite, chalk, phosphatic nodules, cherts; some sodium sulphate and sodium chloride. Coral rags and limestones including shell-limestones.

Tertiary.—Clays, lignite, peat, some ochre; sandstone and limestone.

Laterite.—Iron stone, bauxite, building stone.

Recent.—Alluvial clays and sands, kankar, alkali salt efflorescences, peat; alluvial gold; calcareous tufa and coral limestone.

Coastal sands containing quartz, magnetite, ilmenite, monazite, zircon, garnet, rutile, sillimanite, etc.

CHAPTER II

ABRASIVES

Introduction

Abrasives are materials used in the arts and industries for purposes of grinding, sharpening, polishing, etc. Most industries require the use of abrasives at some stage for preparing the raw materials or for shaping and finishing the products. They are used in the form of pebbles or balls (balls of steel, or pebbles of granite, quartz, quartzite, flint and so on) for pulversing and grinding. Grindstones, pulp-stones and discs may be shaped from naturally occurring stones or by cementing together and shaping crushed abrasives.

Very hard abrasives are used for drilling and etching while softer materials find application in smoothing, polishing and other finishing operations.

The esential properties of abrasives are hardness and toughness. Hardness is the resistance to abrasion while toughness is the power to withstand impact and breakage (i.e., the opposite of brittleness). A rough standard of comparative hardness is provided by Moh's scale, ordinarily used by mineralogists, the numbers indicating the position in the scale :—

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluorite.
5. Apatite.
6. Feldspar.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond.

This scale is by no means equally divided. There is a large gap between corundum and diamond which is filled by certain artificial abrasives. Quantitative measurements can be made with the help of an instrument called sclerometer which consists of a movable carriage on which the surface to be tested is placed horizontally. A steel or diamond point touches this surface. The weight required to move the carriage and just produce a scratch on the surface gives a measurement of the hardness.

Classification

Abrasives can be divided into natural and artificial ones. The natural abrasives include many substances the chief of which are diamond, corundum, emery, garnet and the group called siliceous abrasives. The latter include flint, quartz, silica sand and sandstones, diatomite and tripoli, pumice, etc. Amongst the other materials used are magnetite, feldspar, talc and chalk.

A large number of artificial products are also used as abrasives and polishing media. These comprise carbides of silicon, tungsten, boron, etc.; fused alumina; artificial emery; iron oxide, aluminium oxide, magnesium oxide, etc.

Uses

For disintegrating and grinding, abrasives are used in the form of balls or pebbles in ball mills, the materials to be ground being less hard and tough than the pebbles used. Steel balls, and pebbles of flint, granite and quartz are commonly used in ball mills.

Abrasives may be bonded with shellac, bakelite, rubber, silicate of soda, clay or similar materials and shaped into wheels and discs. After mixing, the material is baked or otherwise treated and finally given the required shape.

Abrasives are also used spread on cloth or paper and fixed thereon with the help of a suitable binder such as glue. Emery cloth, emery paper and sand paper are familiar examples.

Most industries use abrasives in some form or other. A few examples are given below :—

(*a*) For grinding ceramic raw materials, paint pigments and other materials.

(*b*) For drilling through stone, metals, glass, etc. In drilling wells through rock strata, bort (diamond) is now extensively used.

(*c*) For polishing metals, glass, stone and wood surfaces.

(*d*) For carving and sand blasting building and ornamental stones such as granite, marble and sandstone.

(*e*) For polishing leather and wood-work, using coated abrasives (emery cloth, etc.).

(*f*) As grindstones and pulp-stones, which should be hard, tough, compact rocks; as honing stones which must be hard and fine-grained.

(*g*) As an ingredient of polishing soaps, powders, liquid polish, tooth paste, etc., where finely ground abrasives are mixed with other materials.

Distribution

A general description of the more important sources is given here as it is not possible to go into much detail, in view of the large number of materials involved. Some of the important abrasives like diamond, corundum and garnet are treated in separate chapters to which reference may be made for more details.

Diamond.—This is one of the most important abrasives for special purposes such as drilling through rock, metal, precious and semi-precious stones, fine wire-drawing and for the manufacture and finishing of precision tools and instruments. The demand for all types of diamond has increased enormously during recent years and the quantity and value of diamond used in industry now greatly exceeds that used by the jewellery trade.

Diamond used to be mined formerly from strata belonging to the Kurnool System near Banganapalle, Ramallakota, Partial and other places. The neighbourhood of Wajra Karur near Gooty still yields some stones to diligent searchers.

Corundum.—This mineral occurs as a constituent of anorthite-gneisses near Sithampundi in Salem; in syenitic rocks near Pappa-rappatti and Palakod in Salem and in the Sivamalai area near Kangayam in Coimbatore; in some weathered syenitic rocks in stream courses near Uppinangadi, South Kanara; also in some places in the Anantapur district.

It is now mined in the Sithampundi area and used for abrasive purposes.

Spinel.—A greenish black spinel (?hercynite) is found associated with corundum in the deposits near Palakod, Salem. It has been recovered with corundum and used by the abrasive industry.

Emery.—This material is not known to occur in India. The 'emery' from Sanyasimalai in the Shevaroys is only a garnet rock. Magnetite and even dark coloured basic volcanic rocks have been marketed as 'emery' in this country, especially during the recent War.

Magnetite.—It is known that during the War magnetite used to be sold in the market as 'emery' and was in demand particularly by the rice mills (for polishing rice). Magnetite crushed out of magnetite-quartz rocks near Ongole as well as that recovered from stream sands near Polur and Tiruvannamalai are said to have been marketed.

If this material can find a permanent market, the magnetite-quartz rocks of Salem, Trichinopoly and South Arcot can be worked regularly to supply any conceivable demand, as the deposits are very extensive.

Garnet.—This mineral is a common constituent of some mica schists and charnockites and is widely distributed in this Province.

Garnet occurs in large quantities and as large crystals in the schists of parts of the mica belt of Nellore, e.g., near Saidapuram, and the schists here are rich enough in the mineral to be worked. Garnets sands occur in several places along the Coast, the best deposits (which have been worked) being those of Ovari and

Navaladi in the Tinnevelly district. Some streams in the southern parts of Tinnevelly carry sands comparatively rich in this mineral.

A garnet-rich rock occurring in the Sanyasimalai in the Shevaroy Hills has been crushed, graded and marketed as 'emery' or 'garnet-emery' in recent years.

Flint and chert.—The only place where flint is found in the Province is near Sendurai in the Ariyalur taluk, Trichinopoly district, in the Niniyur Stage of the Cretaceous. An irregular thin bed (3 feet thick) of flint boulders is exposed in a nala between Sendurai and Nallampalaiyam (11° 14′ : 79° 12′), for a distance of 50 yards and is covered over by soil on the banks of the nala. The amount available at sight is only a few tons and no opinion can be hazarded about the extent of the deposit, but it is unlikely to yield large quantities.

Pebbles and boulders of chert are seen one to two miles S. and S.S.E. of Vilangudi (11° 7′ : 79° 12′) near Ariyalur, partly within and partly outside a reserved forest. They are embedded in a soft red sandstone. The amount at sight would run to a few hundred tons but the material is not generally compact enough for use in ball mills.

Nodules and lumps of chert are frequently seen, rather irregularly distributed in the Vempalle limestone which is exposed as a band stretching through the Cuddapah, Anantapur and Kurnool districts. The material is very irregular in shape and is not likely to be of industrial use especially as it is very sporadic in distribution.

Pebbles of quartz and quartzite are widely distributed, embedded in the Tertiary Cuddalore sandstones, e.g., west and south of Vallam near Tanjore, near Ayangudi a few miles south of Pudukkottai, and other places. They are generally rather brittle, but it should be possible to select the better quality pebbles for use in ball mills to grind materials which would not be affected by heavy contamination by silica.

Vein quartz from Manapparai in Trichinopoly has been used in ball mills in the ceramic factory at Kundara in Travancore. Doubtless, similar material occurring extensively in quartz veins in many districts can also be used for this purpose.

Grindstone, pulp-stones, etc.—There are numerous beds of quartzitic sandstones in the Cuddapah and Kurnool formations which are locally used as grinding stones.

Quartzites also occur amidst the Archaeans in many districts. Some of them are suitable for use for these purposes.

Granites, compact gneisses and charnockites are used in many parts of the Province as grindstones and mortars for domestic use. Compact, even grained granites and charnockites are shaped into road rollers for local use by the municipalities and the Public Works Department, e.g., in Madura, Trichinopoly, Salem, Arcot, Nellore and Bellary.

Honing stones.—Compact, fine-grained and hard stones are used for this purpose. There are numerous beds of fine-grained sandstones and siliceous and calcareous slaty shales in the Cuddapah and Kurnool formations quite suitable for this purpose, though they do not seem to have received the attention they deserve.

Lydian stone.—King (*Mem. Geol. Surv. Ind.*, VIII, p. 48) mentions the presence of a bed, 9-18 inches thick, of lydian stone occurring in the Kurnool strata near Nandikotkur. Similar material occurs elsewhere in the same strata.

Abrasive silt.—About 2 miles north of Pulivendla (and half a mile west of Ulimella village) is a deposit of silty sand below a thin soil cap, occupying an area of 250 yards by 40 yards. The bed is 3 feet thick. It is incoherent, light buff to ash-grey in colour and consists of very fine sub-angular grains of quartz with some clay. Most of the material (about 90 per cent.) is between 120 to 150 mesh in size. It appears to be a lake deposit of recent geological age. It is used locally as an abrasive metal polish. The deposit is estimated to hold 8,000 to 9,000 tons of this material.

Diatomite.—No diatomite or tripoli is known to occur in the Province. Some siliceous and calcareous beds of Upper Cretaceous age near Sedarappattu (a few miles north of Pondicherry) which contain abundant micro-fossils, were carefully examined but did not reveal the presence of diatoms. The Niniyur beds in the Trichinopoly district have so far not been found to contain any diatomaceous beds.

Silt containing diatoms is found on the banks of the Buckingham Canal bordering the Pulicat Lake north of Madras, but the proportion of diatoms in it is very small.

Other abrasives.—

Feldspar is widely distributed in the Province and large quantities can be had from the pegmatites traversing the Archaean gneisses and granites. Abundant supplies will be available from Nellore, West Godavari, Arcot, Trichinopoly, Salem, Madura, Tinnevelly and Coimbatore.

China clay and other types of clay are found in Kurnool, Cuddapah, East and West Godavari, Chingleput, South Arcot, Kanara and Malabar. They can be used as polishing materials.

Chalk.—Thin veins of chalk, mixed with clay along the margins, occur in limited areas in the Uttattur Stage of the Trichinopoly Cretaceous near Karai and Uttattur.

Fairly large deposits of chalk or white chalky clay occur at Palkur (15° 25′ : 78° 15′) and Nandavaram (15° 22′ : 78° 17′) in the Banganapalle State, and near Chinna Malkapuram (15° 22′ : 77° 58′) in Kurnool district. The material is friable and soft and can be used as soft abrasive or polishing powder.

Steatite.—Talc-schist and steatite occur in several districts, especially Kurnool, Bellary, Salem and Coimbatore. Much of the material is of the nature of potstone but some good steatite is obtainable in several deposits.

Artificial abrasives.—The chief artificial abrasives are carborundum (silicon carbide) and fused alumina. Both are manufactured in the electric furnace. A substance resembling emery can be produced by the fusion of ferruginous laterite. Certain metallic carbides are also made for special purposes.

Prospects

There is apparently only one factory in this Province (Ajax Products, Ltd., Madras), manufacturing graded and coated abrasives, and wheels and discs, and there is scope for the expansion of the industry and for one or two more factories in other parts of the Province.

The resources of the Province in natural abrasives is fair as corundum, garnet, quartz and other siliceous materials are available.

During the last few years fused lateritic material from the Shevaroys is being manufactured by Mr. E. K. Dickins under the trade name of **alirox** which is said to be as good as natural emery.

Millstones and grindstones are made locally in many places but there is no organised industry. There is room, therefore, for a well-organised concern to undertake the manufacture of all types of abrasives and polishing media on a large scale, in view of the availability of raw materials.

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CHAPTER III

ANTIMONY

Stibnite (Sb_2S_3) the chief ore of antimony, is a soft black mineral occurring as bladed or needle-shaped crystals and powdery masses. It occurs in metalliferous veins in association with other sulphides. In the East, the mineral has been used, because of its softness, as *surma,* for blackening the eyebrows and eye-lashes.

Distribution

Bellary.—Sulphide of antimony was reported to be present in the schists of the Sandur State near Ramandrug, by Kelsall (Manual of the Bellary district, 1872, p. 93). Later observers have not confirmed this. It is likely that the manganese ore occurring in this locality was mistaken for stibnite.

Cuddapah.—Newbold stated (*Mad. J. Lit. Sci,* X, p. 125, 1839) that antimony ore was found at Jangamrazupalle in the Nallamalai hills, where lead ores are known to have been worked. Either the material is rare or something else (possibly galena, the lead sulphide) has been mistaken for this.

Vizagapatam.—In the Manual of the Vizagapatam district (1869, p. 155), Carmichael has mentioned that antimony occurs at Kodur, which is now known to be the site of a manganese mine. The material was exhibited at the Madras Exhibition in 1857. It was shown by Dr. A. Scott (Balfour: 'On the iron ores: the manufacture of iron and steel, etc.', Madras, 1855, p. 238) that this was manganese ore.

It would appear therefore that the occurrences so far reported are either mistaken or so scanty that they have not been confirmed by later observers.

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CHAPTER IV

ALUMINIUM SULPHATE

Alum is said to occur as efflorescences in clay strata containing thin layers of pyrites in the cliffs between Varkala (8° 44′ : 76° 46′) and Ajengo (8° 40′ : 76° 49′). These alum-clays are about 25 feet thick and form part of the Warkalli (Varkala) beds of Miocene age. (King: Warkilli beds, etc., Travancore. *Rec. Geol. Surv. India,* XV, pp. 93-102, 1882).

Alunogen [$Al_2(SO_4)_3.16H_2O$] is known to occur as efflorescence on the upper slopes of a hillock flanking the Nerukona *vanka* (stream) about three miles S.S.W. of Mittamidapalle (14° 26′ : 78° 44′) in the Ganganapalle Reserved Forest, Cuddapah district. The rocks are Vempalle shales of the Cuddapah system. The material is said to be found in a zone 300 feet long (horizontal) and 15 feet thick (vertical) about 50 feet below the top of the cliffs. It occurs in the form of fine tufts of fibrous material with pink colour, showing occasional patches of blue tint which proved to be of copper sulphate. (Krishnan: *Rec. Geol. Surv. India,* LXVIII, p. 246, 1934.)

Aluminium sulphate generally occurs in nature by the action of sulphuric acid derived from pyrites (or other sulphide) on aluminous shales. It is lixiviated and a potash salt added to get alum. In some cases, if there is alkali in the shales or clays, alum may be formed as efflorescence.

CHAPTER V

ASBESTOS

The term asbestos (Telugu *ratinara;* Tamil *Kalnar*) is used for certain minerals having a fine fibrous structure. They are flexible and possess a degree of tensile strength, resistance to heat and chemical attack. They belong to the amphibole and serpentine groups of minerals.

Amphibole group.—Anthophyllite, tremolite and actinolite are found in the form of mass-fibre (interlaced, matted or radiating) and slip-fibre (parallel groups). They are generally brittle and only occasionally sufficiently strong for making into filter-pads. These varieties are resistant to heat and to chemicals.

Crocidolite (soda-iron amphibole) and amosite (iron-magnesia amphibole) contain appreciable amounts of water of crystallisation and are less resistant to heat than the other amphibole varieties, but are equal to them in resistance to chemical attack. They occur both as cross-fibre (fibres perpendicular to the length of the veins) and slip-fibre, in lengths varying from a fraction of an inch to 10 or 12 inches. They can be spun into coarser yarn than chrysotile, They are used largely in heat insulating compositions.

Serpentine.—The finely fibrous form of serpentine is called chrysotile. It yields very thin silky fibres with high tensile strength and is largely in demand for making asbestos textiles. Because of its high water of crystallisation (10-13 per cent.) its resistance to heat is less than that of most of the amphiboles, excepting crocidolite. It is put to all types of uses.

The amphibole types are derived from metamorphosed basic igneous rocks. Crocidolite and amosite are associated with ferruginous quartzites (banded iron formation) and ferruginous slates in South Africa which is their only source. Chrysotile is always associated with serpentine which may be a product of hydrothermal alteration of ultrabasic igneous rocks (perioditites and dunites) or of dolomitic limestones.

In the mining and preparation of asbestos an effort is made to recover as much as possible of long fibre without injuring it. The material is beaten up (cobbed) and screened into various grades. Spinning fibre is ¼ inch or longer, while shingles and paper grades are between 4 to 10 mesh usually. Waste fibre is mostly shorter than 10 mesh.

Uses

Asbestos yarn made from spinning grade fibre is manufactured into textile for fire-proof clothing, aprons and gloves, curtains, brake

linings, insulating mats, asbestos rope and wick. Magnesia blocks (with 15 per cent. asbestos) are often used for heat insulation.

Asbestos of shorter grades is employed in compositions using synthetic resins, rubber, paper, cement and plaster. Spinning grade asbestos goes into the making of brake linings and clutch-facings. The more brittle types are made into filter pads for filtering acids, chemicals and organic juices.

Distribution

Cuddapah.—Chrysotile veins are found in serpentine developed at the contact of a trap sill with the Vempalle dolomitic limestone in several places in this district. Some veins occur also in the trap itself at the contact. The serpentine zone may be several feet thick but the asbestos is confined to a width of 2 to 3 feet from the contact. The trap is of the nature of olivine dolerite and of late Cuddapah age.

The asbestos is of the cross-fibre type including much brittle variety. The veins range in thickness from a fraction of an inch to as much as 7 inches, the average being around ¼ inch. A vein of excellent chrysotile, 6 to 7 inches thick, was worked in 1941 in a part of the mine over a length of several yards in the Lakshmana mine at Chinna Kudala (14° 25′ 30″ : 78° 10′) worked by Mr. A. Krishnappa. The veins behave capriciously as regards thickness and continuity and are rarely uniform for more than 30 or 40 feet. The undisturbed vein material is nearly white, pale green or pale yellow and occasionally translucent.

The best developed zone is in the Vempalle limestone stretching nearly 7 miles from near Lingala (14° 30′ : 78° 7′) to Brahmanpalle (14° 25′ : 78° 12′), a little to the west of Pulivendla. Portions of this near Brahmanapalle and Chinna Kundala, contain better and thicker veins than the rest. This zone has been responsible for practically all the output from this district.

Short workable zones are found near Lopatanutula (14° 30′ : 78° 6′) ; near Tallapalle-Velamvaripalle (14° 20′ : 78° 23′ 30″) ; N.N.W. and N. of Vempalle (14° 22′ 30″ : 78° 27′ 30″) near Errapalle (14° 28′ 30″ : 78° 33′) and on the eastern side of hillock ·964 about 6 furlongs W.S.W. of Rajupalem (14° 26′ : 78° 31′).

Kurnool.—Commercially unimportant occurrences of a similar character are known in serpentinised Vempalle limestone a little to the east of Malkapuram (15° 21′ : 77° 59′), Chinna Malkapuram (15° 22′ : 77° 58′ 30″) and about a mile east of Joharapuram (15° 49′ : 78° 4′).

Anantapur.—A few veinlets are seen in the same geological horizon about three-fourths of a mile south-east of Vengannapalle (14° 58′ : 77° 48′).

Salem.—Small veins of chrysotile were found by Rao Bahadur M. Vinayak Rao near the southern extremity of the magnesite area of Chetti Chavadi jaghir near Salem junction. Balfour also mentions occurrences near Salem.

Rather brittle serpentine asbestos occurs in association with steatite and magnesite at Siranganur (11° 44′ : 78° 46′ 30″) about 3½ miles north-west of Taramangalam. The material is up to 3 or 4 inches long and is used by the local people for making tooth-powder.

Small patches containing asbestos veins occur amidst the altered ultrabasic rocks in the magnesite area of Valaiyapatti (11° 7′ 30″ : 78° 14′) south of Namakkal. The material is of the slip-fibre type and up to about 10 or 12 inches long but of poor tensile strength. Some quantity may be found in this deposit. A new well put down in 1945 in the hamlet 1 mile south of Valayappatti (near mile 43/4 on the Namakkal—Trichinopoly road) showed the presence of similar asbestos at a depth of 20 feet. The vein was said to extend across the well.

Amphibole asbestos is reported to occur close to the railway track between Tholasampatti and Mechcheri on the Salem-Mettur branch line of the South Indian Railway. A sample of the material shown to me was 8 inches long and of the slip fibre type. It has not been possible to investigate this occurrence as it is occupied by an irrigation tank. It would appear that this may contain a small tonnage.

Nilgiri.—An occurrence of anthophyllite asbestos was reported near Cherankode (11° 33′ : 76° 20′) but no details are available.

Coimbatore.—The district manual by Nicholson mentions an occurrence near Perundurai (11° 17′ : 77° 36′). A specimen of amphibole asbestos received by the Geological Survey of India from the Director of Industries, Madras, was said to have come from a locality 6 furlongs distant from the Coimbatore-Mettuppalaiyam railway track. The exact locality is not known but the material was of poor quality.

According to the local Revenue officers, soft long fibred but weak asbestos of the amphibole variety was recently met with in newly dug wells in survey Nos. 456, 459 and 460 of Muthampalaiyam (Muddampalaiyam 11° 12′ : 76° 57′ 30″) south of Karamadai railway station. A fair quantity is said to be available.

I was informed by a forest officer that there is an occurrence near Bargur (12° 48′ : 77° 32′) in the Bhavani taluk, approachable from Bhavani and Andiyur.

Production and Prospects

The only asbestos deposits worked in this Province are those of the Brahmanapalle-Lingala area in the Pulivendla taluk of the Cuddapah district. The discovery of asbestos is said to have been made first in this zone accidentally in 1924 by a resident of Lingala while digging a well. In that year specimens were sent to London and exhibited at the British Empire Exhibition at Wembley. The Mysore Development Syndicate and their successors the Mysore Asbestos Mines, Ltd. worked the deposits between 1924 and 1931 and opened up a number of mines along the outcrop and followed the asbestos zone down the dip of the Vempalle limestone for a distance of up to 200 feet. The dip of limestone in this zone is around 18° to 20° in a N.N.E. direction. The above company closed down work in 1931 or 1932 and relinquished leases soon after. Since then Mr. A. Krishnappa has taken mining leases of parts of this zone and has been working near Chinna Kudala from about 1938 or so.

A detailed examination of this zone was made by the writer and his colleague Mr. M. S. Venkatram early in 1941. The Government of Madras had seven shallow drill holes put down at selected spots near Brahmanapalle and Chinna Kudala in the same year. These confirmed the fact that the asbestos zone continued along the trap-limestone contact which follows the dip direction.

The reserves estimated in the Brahmanapalle and Chinna Kudala areas for a total length of 3 miles of asbestos-bearing serpentine zone along the strike, and 1 furlong along the dip is of the order of 250,000 tons of good chrysotile of all grades. A good part of this material will have a length of 0·1 to 0·3 inch.

Owing to the irregularity of the veins and the comparatively poorer development in the other deposits in Cuddapah, it is not possible to estimate the reserves without doing considerable prospecting work. Two or three of the deposits in Salem and Coimbatore, which are said to be promising by the informants, have not yet been examined by the Geological Survey of India.

OUTPUT OF ASBESTOS (CUDDAPAH).

	Output (Tons)	Value (Rs.)
1924	13·5	5,400
1925	16·0	4,796
1926	18·4	5,529
1927	22·0	6,604
1928	8·5	1,275
1929	88·4	3,160

	Output (Tons)	Value (Rs.)
1930	33·2	1,190
1931 to 1941	No production.	
1942	60	96,060
1943	33	50,325
1944	58	85,759
1945	38	4,717
1946	18	20,044

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8 JUL 1952

CHAPTER VI

BARITE

Barite (also referred to as Barytes) is the sulphate of barium (65·7 per cent. BaO) occurring as crystals and in a massive form, with white, grey, or buff colour. It is distinguished by its high specific gravity (4·3 to 4·5). It can be easily powdered because of its brittleness. The other important barium mineral is the carbonate, Witherite, but no deposit of this is known in India.

Barite is commonly known as *muggu rayi* in Telegu (*Kolakkal* in Tamil) as the powder is commonly used by Hindus for drawing patterns on the floors.

Barite occurs commonly as veins in association with quartz and carbonates in joint planes and fissures, and sometimes as a replacement of the country rock, particularly limestone and dolomite. Both fissures and replacement veins occur in the Ceded districts, either in the dolomitic limestones of the Vempalle stage or in the traps intrusive into them. The solutions responsible for the formation of barite are thought to be genetically connected with the traps of Cuddapah age.

The mineral is practically all mined open-cast, but there are one or two properties in Cuddapah where some underground mining has been done. The veins are followed along their strike and dip and the material hand-picked and sorted at the surface into first grade (pure white without stains) and second grade (material with stains and inclusions). Only 5 to 10 per cent. of the product of the mines is of the first grade. There is a great disparity in price between the two grades, the ruling prices during the War being Rs. 60 per ton for the first grade and Rs. 18 to 20 for the second. Most of the producers sell it in the lump form but two or three have grinding mills in which it is powdered to 300 mesh and marketed. The prices of ground barite is around Rs. 120 per ton for the first grade and Rs. 75 for the second.

Uses

The chief use of barite is as a filler in paints, textiles, paper, rubber, linoleum, gramophone records, artificial ivory, printing inks, and soaps, where its inertness and density are useful. It is used as an ingredient of certain types of optical glass. Plaster containing the mineral is used for covering the walls of rooms where X-ray sets function. Cheaper grades are used for weighting the drilling muds for oil-well drilling.

The major part of production goes into the paint trade, particularly into the manufacture of **lithopone** which consists of a mixture of 70 per cent. barium sulphate and 30 per cent. zinc sulphide.

Lithopone is made by calcining barite with carbon to reduce it to the sulphide, lixiviating the calcine and mixing it with a solution of zinc sulphate. The precipitate is lithopone, which is washed, dried and ground. Lithopone is used mixed with paints, and also in the lacquer and varnish industry.

Barium chemicals are made generally from the sulphide which is obtained by reducing barite with carbon. **Blanc-fixé** which is obtained by the reaction of a solution of barium sulphide and sodium sulphate is a valuable paint material. Barium hydroxide is used in the manufacture of soap, cellulose, lacquer, etc.; the nitrate in pyro-technics, explosives and medicine; the chloride in water-softening, and in the textile and leather industries.

Barium also enters into the composition of certain alloys, especially with magnesium, aluminium and nickel. A nickel-barium alloy wire coated with barium and strontium oxides is used in radio-valves on account of its high thermionic emission.

Distribution

Barite deposits are found in large numbers in the Ceded districts a few being quite large, and containing veins up to 30 feet thick and many yards long. A few are known in other districts also. Descriptions of working quarries and abandoned pits are given in the Memoir by Coulson and in the later reports by Krishnan, Venkatram and Balasundaram, to which reference may be made for details. A list of localities in the Ceded districts is given below, which are described in the above reports, and short descriptions are given of deposits in other districts.

Anantapur District.

	Lat. °	′	″	Long. °	′	″
Mudigubba	14	21	0	77	59	0
Nerijamupalle	14	32	30	78	1	0
Daditola	14	35	30	77	58	30
Ellutla	14	40	0	77	54	30
Madugupalle	14	42	30	77	54	0
Dosaledu	14	46	30	77	54	30
Obalapuram	14	47	0	77	54	30
Venkatampalle	14	47	30	77	50	0
Mutssukota	14	51	0	77	52	30
Sanjivapuram	14	48	30	77	54	30
Tabjula	14	54	0	77	49	30
Turkapalle	14	56	30	77	48	0
Chintalacheruvu	14	59	30	77	46	0
Konapuram	15	0	30	77	48	30
Kondampalle	15	2	30	77	47	0
Krishtipadu	15	4	0	77	46	30
Lakshmupalle	15	7	0	77	49	30

Kurnool District.

	Lat. °	′	″	Long. °	′	″
Nallamekalapalle	15	7	30	77	47	0
Boyanapalle	15	8	30	77	49	30
Narayanapuram	15	9	30	77	47	0
Peddapaya	15	10	0	77	50	30
Rangapuram	15	14	0	77	49	30
Hussainpuram	15	14	0	77	50	0
Ramapuram	15	17	0	77	52	0
Kochcheruvu	15	19	0	77	51	30
Chandrapalle	15	20	30	77	49	0
Kamalapuram	15	21	0	77	56	0
Kottapalle	15	22	30	78	2	30
Valasala	15	23	30	77	58	30
Ambapuram	15	23	0	78	5	30
Rahimanpuram	15	24	0	78	3	0
Basavapuram	15	24	30	78	38	0
Gutupalle	15	25	30	78	3	0
Komururikottala	15	26	0	78	5	0
Tapasikonda	15	27	30	78	3	30
Balapalapalle	15	27	30	78	6	30
Papasanikottala	15	27	30	78	5	0
Kolumalapalle	15	28	30	78	8	0
Janapalacheruvu	15	28	30	78	9	30
Musalayyacheruvu	15	29	30	78	4	0
Gattimanikonda	15	32	0	78	11	0
Gadidemadugu	15	46	30	78	9	0

Cuddapah District.

	Lat. °	′	″	Long. °	′	″
Razampeta	14	14	0	79	38	30
Bakkannagaripalle	14	20	0	78	22	0
Midipenta	14	20	0	78	19	0
Rachegaripalle	14	21	0	78	19	0
Velpura	14	21	30	78	16	0
Polatala	14	22	0	78	41	0
Kottapalle	14	22	0	78	21	30
Bestavaripalle	14	22	30	78	15	0
Vempalle	14	22	30	78	27	30
Nandipalle	14	22	30	78	24	30
Tangedupalle	14	23	0	78	29	0
Mittamidapalle	14	25	30	78	44	0
Chimalpenta	14	26	0	78	35	30
Uppalapalle	14	26	0	78	31	30
Rajupalem	14	26	0	78	31	0
Ippatla	14	32	0	78	4	30
Karnapapayapalle	14	32	0	78	4	30
Parnapalle	14	34	0	77	58	30

Nellore District.—Two hillocks about 3 miles east of Narravada (14° 54′ : 79° 26′) show veins of barite traversing the foliation planes of the mica schists and also dissemination in the neighbourhood of the veins. They strike N.W.-S.E.

North Arcot District.—About a mile to the south and south-west of Alangayam (12° 38′ : 46°) there are two hillocks one on either side of the road connecting this place with Mittur, a few miles to the south-west. These two hills and the intervening ground are largely occupied by pyroxene gneisses traversed by abundant veins of barite associated with quartz. A lens-like body occurs also just east of Andiyappanur 7 miles south of Alangayam, running N.E.-S.W. The main mass is roughly dumb-bell shaped in plan and occupies nearly 4 sq. miles judging from the sketch map accompanying Sir Thomas Holland's description of the deposit.

The individual veins vary in thickness from a fraction of an inch to several feet and lie in all attitudes. The veins are apparently connected with the granitic rocks and have been formed by hydrothermal agencies during a late stage of the igneous activity. The proportion of barite in the veins varies greatly. The average specific gravity of 60 specimens collected by Holland was 3·005 which gives a barite content of 30 per cent. in the veins. The associated impurities are pyrite, galena, ilmenite, hematite and limonite. A chemical analysis of the barite showed 94·15 per cent. $BaSO_4$, 4·01 $CaSO_4$, 0·63 SiO_2 and 0·93 per cent, ferric oxide and alumina. The deposit has not been examined in detail to assess the reserves.

Trichinopoly.—The celestite in the Cretaceous strata in a small area south-east of Karai (11° 8′ : 78° 53′) is found to be interbanded with barite. The presence of barite was recognised by the lessees working in this area only in 1940, though the village folk apparently knew of it as *kolakkal* for many years. It is fibrous like celestite but has a more silky lustre and 'softer' look and the fibres more frequently bent. It can be distinguished easily by its look after a little experience. The deposit is not large but may perhaps yield a couple of hundred tons.

Coimbatore.—Veins and lenses of barite are noticed in the hillocks about half a mile west of Kurichchi (11° 34′ : 77° 42′), which is some 10 miles north of Bhavani. The hillocks trend N.E.-S.W. and are composed of gneisses intruded by granite and pegmatite. According to Mr. N. K. N. Aiyengar who visited the occurrence in 1945 (Progress Report for 1944-45) the veins are up to 15 feet long and up to 7 or 8 inches thick and are made up of barite, quartz and feldspar. They are found on the flanks of the hillocks impersistently for a distance of 1 mile, following the strike of the gneisses. It is also interesting that this barite has been collected by the women folk of the village for many years as 'kolakkal' and in fact information about the occurrence was first supplied by them. An analysis of the barite

gave 63·48 per cent. BaO (95·3 $BaSO_4$), 0·58 per cent. CaO, 0·32 per cent. MgO and 0·16 per cent. SiO_2. The deposit may yield a few hundred tons.

The occurrence of barite in the Ceded districts has been known for a long time and it had been used by the people as *mugguragi* and for medicinal preparations. Newbold reported in 1844 that barytes is found in the lead ores of Basavapuram and this was later confirmed by Wall and King. Gopalakristnamah Chetty states in the Kurnool district manual that: "Kapura Silajit or sulphate of baryta is found in Jaladurgam and Chandrapalle in Pattikonda taluk and in several villages of the Ramallakota taluk connected with the Erramalas. It is pounded into powder and used by native women in ornamenting the floor. It is also used in medicine".

Interest began to be taken in the search for and development of the deposits in 1910 by A. Ghose and others. The first record of production is in the year 1918 but the mineral must have been won in a small way before that. Up to 1930 the output was entirely from the Kurnool district. In 1931 Cuddapah began production and was soon joined by Anantapur also.

OUTPUT OF BARITE.

Year	Output (Tons)	Value Rs.
1918	2,724	44,215
1919	2,590	15,615
1920	678	15,528
1921	1,457	47,603
1922	1,742	41,500
1923	1,603	22,749
1924	783	11,341
1925	580	7,760
1926	350	1,400
1927	851	5,550
1928	620	4,610
1929	802	5,151
1930	5,633	42,578
1931	5,493	42,240
1932	2,474	26,474
1933	5,544	40,447
1934	3,259	30,443
1935	4,562	26,060
1936	4,923	14,086
1937	15,535	1,47,870
1938	7,932	28,052
1939	8,615	55,897
1940	17,740	41,936
1941	22,145	43,808
1942	10,008	80,124
1943	7,894	93,929
1944	13,567	1,45,253
1945	22,703	3,09,385
1946	28,874	3,64,330

India's output is barely 1 per cent. of the estimated annual world output of 800,000 tons. The deposits in the Ceded districts are large and extensive and are being worked in shallow open-cast quarries. Though no estimates have been made of the resources, it is believed that they are large enough to last for many years at the present rate of production.

The main market for the material is the paint industry in Northern India and to a certain extent for oil well drilling in India and neighbouring countries. Much barite is now condemned to a low price because it is stained and classed as second grade. There is scope for research in improving this material and in recovering more from thin veins and disseminations. A local market will be created if a paint industry is established within the province and also the manufacture of barium chemicals.

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CHAPTER VIII

BAUXITE

The term bauxite is used for the alumina-rich variety of laterite. Laterite is a mixture of the hydroxides of iron, aluminium and manganese with some silica and titania. It is formed under humid tropical conditions with alternating wet and dry seasons. During the process of alteration of the rock, the alkalies, alkaline earths and silica are removed, leaving a residiuum of the hydrated oxides of iron, aluminium and manganese. Any rock containing these latter may give rise to laterite. It is not clear whether the formation of kaolin and clay is an intermediate stage.

There are two main types of bauxite, one formed from basic rocks like the Deccan Traps or felspathic rocks like granites and gneisses, and the other from the concentration of the aluminous material in limestones and dolomite by the removal in solution of calcium and magnesium. The first is the *laterite type* and the second *terra rosa* type.

Bauxite may be white, grey or brown in colour, and compact, pisolitic or vermicular. It may be waxy in appearance and feel, or earthy and finely crystalline. Large deposits generally form rounded hill tops, as in the Shevaroys and in parts of the Deccan trap country. The top is generally rich in iron and below this comes a layer of aluminous laterite. This grades, down below, into a lithomarge or siliceous clay which in turn overlies the parent rock.

Uses

Bauxite is the raw material for the manufacture of alumina which is used in the extraction of aluminium by an electro-thermal process. Before the War, bauxite for this purpose was required to contain over 52 per cent. Al_2O_3 and less than 6·5 per cent. ferric oxide and 5 per cent. silica. Somewhat inferior grades can now be used. Bauxite is used for making refractory bricks which are employed in smelting furnaces and cement kilns. It is an important ingredient in high-alumina cements (Ciment fondu) which set quickly and are particularly valuable in saline surroundings. Alums and aluminium chemicals are made from alumina or high grade bauxite low in iron, these being useful in water and sewage treatment, and in the tanning and dyeing industries. Bauxite is used for filtering and decolourising oils, and Indian bauxite was used only for this purpose until a few years ago. By fusing bauxite, artificial emery and fused alumina abrasives are made.

Deposits

The only deposits known at present in this Province are those forming about half a dozen peaks, including the Shevaroyan and Sholakaradu, in the Shevaroy hills. The present lessee of these deposits (Mr. E. K. Dickins) has prospected some of them and shown that there is much good material. The total quantity of all grades in some of these deposits is of the order of 6 to 7 million tons of which perhaps a third would be of high grade. The Shevaroy bauxite is generally easily soluble in caustic alkalies and is claimed to be suitable for the manufacture of alumina. It is now being used for making artificial emery (marketed under the name of 'Alirox') on a small scale.

Detailed prospecting of the Shevaroy deposits should be undertaken in order to assess their industrial importance and usefulness for making alumina and refractories. Other areas in which useful deposits are likely to occur are the Eastern Ghats of Vizagapatam and Godavari, the Palni and Nilgiri hills, and the laterite-bearing areas of the Western Ghats in Kanara and Malabar.

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CHAPTER VIII

BUILDING STONES

Amongst the materials used for building purposes, stones play a very important part. This Province abounds in various types of stones useful for general building and for ornamental purposes and they have been used to good effect in the anceint buildings and structures belonging to various periods. Examples can be seen amidst the temples, forts and palaces in many parts of the Province—Cape Comorin, Rameshwaram, Madura, Trichinopoly, Srirangam, Tanjore. Conjeevaram (Kancheepuram), Tirupati, Amaravati, Nagarjunakonda, Hampi, etc.

The essential characteristics of building stones are strength and resistance to weathering (durability in general). The textures and structures of rocks enter into these considerations as they affect their durability. Some igneous and metamorphic rocks are amongst the strongest, with crushing strengths varying between 800 and 1,500 tons per square ft. Medium grained and compact rocks are stronger than coarse ones. Similarly porosity, presence of cracks and joints, nature of the cementing medium and its strength (in sedimentary rocks) have all an important bearing on the durability and strength. Heat and cold, *i.e.*, the rapid alternation of high and low temperatures, produce expansion and contraction of the mineral grains along whose boundaries weakness is produced. Percolating water (rain water and ground water) have chemical and physical effects on stones, which may in some cases be very deleterious.

Types of stones available

The most extensively used rocks in this Province are granites, gneisses and charnockites which are widely distributed. Both grey and pink granites and gneisses, the latter often handsomely banded, are available. Charnockites are amongst the most durable stones known and have been used in the construction of numerous temples, forts, bridges and other structures. The rock-cut temples and sculptures of Mahabalipuram, south of Madras, are in charnockite.

The garnetiferous gneisses known as khondalites are extensively developed in the Circars but they are generally inferior stones as they show a tendency to develop a rough pitted surface and to wear away gradually when exposed to the weather.

Quartzites and quartz-schists are found in many places and are used mainly as slabs for paving purposes. The most popular stone for paving is, however, the 'Cuddapah Slab', a flaggy impure argillaceous limestone in the Jammalamadugu formation, extensively developed in Kurnool, Cuddapah, Anantapur and Guntur. The Kundair formation also yields some slabs in the Kurnool district.

Limestones, both sedimentary and metamorphosed, are found in several districts. The sedimentary limestones include those of the Cuddapah and Kurnool and Cretaceous systems. Amongst these there are beautiful marbles, white, coloured and variegated, but they have not yet been properly developed for use.

Slates are found along the border of Nellore and Kurnool districts near Markapur and Cumbum where they are worked. Upper Gondwana sandstones are used in Chingleput, Guntur and West Godavari whereas Recent Coralline limestone and Calcareous grit of the Coastal tract are used in Ramnad and Tinnevelly districts.

Distribution

Vizagapatam and East Godavari.—The chief rocks of the district are khondalites and charnockites, but limestones occur in the hill tracts. Excellent marbles are available at Borra near Anantagiri.

West Godavari.—Gneisses, khondalites and charnockites occur in the interior while a large stretch is occupied by the Chintalpudi sandstones and the Upper Gondwana formations, these yielding sandstones for local use.

Kistna.—The formations here are similar to those of the Godavari district, but there is an area of limestones and sandstones in the Jaggayyapet area adjoining the Kistna River.

Guntur.—A part of the district is occupied by good massive and banded gneisses and by charnockites which are quarried, (*e.g.*, the Kondavidu hills). Khondalites, Gondwana sandstones and flags are quarried near Paidipadu, Tangellamudi, Vemavaram and other places.

There are good flagstones, limestones and excellent marbles in the Palnad tract, the last being obtainable from near Rentachintala, Piduguralla, Dachepalle and other places close to the Guntur—Macherla railway line.

Nellore.—Both massive and banded gneisses are fairly well distributed in this district. A band of good granitoid gneiss is exposed in the Swarnamukhi valley and another band passes through Kalahasti and Venkatagiri in a N.N.W.-S.S.E. direction. A porphyritic gneiss with white feldspars occurs west of Kalahasti while a similar type is worked near Kanigiri. Granite is quarried for local use in Podili and Darsi taluks. The banded epidote rock occurring near Edavalli (15° 28′: 79° 30′) can be used as a decorative stone. Laterite is quarried nearer the Coast for building purposes. There are several bands of quartzites, some yielding good flagstones near Sitaramapuram and Chundi. Occasionally they are greenish as to the west of Picherla Konda and near Massavaram.

Cuddapah and Kurnool.—The Cuddapah basin occupying the Cuddapah, Anantapur and Kurnool districts contains important ridges of sandstones and quartzites which yield some stones suitable for use in building and paving. These are prominently displayed near Cumbum and Markapur, in the Velikonda hills, in the Tirupati hills (Chittoor district), in the area west of Pulivendla, and other places.

The Vempalle stage limestones are generally high in magnesia and are at present of limited use. The Jammalamadugu limestones include both massive limestones eminently suitable as a building and ornamental stone, as well as the flaggy type ('Cuddapah Slabs') which is extensively used for paving. These are quarried at many places in these districts.

Slates are quarried near Cumbum and Markapur and used for paving, roofing and as school slates.

Where trap rocks are developed, *e.g.*, near Pulivendla they are used locally as building stones.

Bellary.—Outcrops of excellent granite and gneiss are developed extensively in this district and white, grey and pink varieties, both banded and non-banded, are quarried in many places mostly for local use. Some of these are handsome stones of high decorative value when polished. Fine examples of these can be seen in the ruins of the capital of the Vijayanagar Kingdom at Hampi near Hospet.

Amidst the Dharwarian rocks of this district are some banded jaspers which can be used as ornamental stones.

Chittoor, Arcot, Salem.—The chief types developed here are charnockites, gneisses and granites and quartzites.

Crystalline limestones are also used when available, as in parts of Salem.

Coimbatore and Nilgiri.—The Nilgiri mountains are composed largely of charnockites while the plains contain gneisses. These are quarried for local use.

Trichinopoly.—Excellent granite gneisses are found especially to the south of the Cauvery River. The crystalline limestones in the Kadavur Zamindari and the cretaceous limestones in the Perambalur taluk find local use. Charnockites are also available in this district, particularly in the Perambalur and Musiri taluks.

Madura-Tinnevelly.—Charnockites, granites, hornblendic gneisses and garnetiferous gneisses are extensively distributed in this district. Some excellent pink granites are developed near Madura and Aruppukkottai. The crystalline limestones near Ambasamudram and other places have not been much used for building purposes. On the coastal tract are the Tertiary calcareous grits and tufaceous limestone which are quite popular building stones.

Ramnad-Pudukkottai-Tanjore.—In the interior of these are good gneisses, especially in the southern areas. Tertiary sandstones of different degrees of hardness are extensively quarried in Pudukkottai with Tanjore at several places. These sandstones are often associated with laterite which is also a popular building stone in Chettinad, Sivaganga and in the Pattukkottai taluk. The laterites and sandstones extend northward along the Coastal region into South Arcot and further north.

Building stones (including bricks) are very extensively used, almost everywhere, but the statistics relating to them are very unreliable. Even where the buildings are actually constructed of bricks, bamboo, timber, etc., a certain amount of good stone is often used at plinth level, for sills, steps, pillars, etc., and for paving courtyards. Unfortunately, the building stone industry is still run on the basis of individual effort, except when the Public Works Department take to quarrying. Even then, because of the lack of sustained and systematic effort, quarrying follows primitive methods. There is scope for the development of good modern stone-quarrying industry in various parts of the Province, so that the different types of good stones present could be made available to the public easily and at reasonable cost.

CHAPTER IX

CHROMITE

The mineral chromite is the chief ore of chromium and has the theoretical formula $FeO \cdot Cr_2O_3$ which would correspond to a Cr_2O_3 content of 68 per cent. The natural mineral however contains appreciable quantities of magnesia, iron and alumina corresponding to a formula $(FeMg)O. (Fe,Al,Cr)_2O_3$. Chromite is black in colour and is distinguished from magnetite and ilmenite by the brown tinge of its streak (powder left when rubbed or drawn across unglazed porcelain). It has a hardness of 5·5 and specific gravity of 4·4-4·5. It is generally found in association with highly basic (magnesian) igneous rocks such as dunites, peridotites or pyroxenites, forming veins, lenses, pockets or granular disseminations.

Uses

Chromium is an important alloying element with steel, the metal being usually introduced as fero-chrome which is manufactured from chromite in the electric furnace. The electrolytic deposition of a thin layer of chromium (chrome-plating) on metals protects them from oxidation.

There is a large range of alloys containing chromium and iron, nickel, cobalt, tungsten, etc. Low chromium steels (up to 5 per cent. Cr.) are used in armour plating. Compositions with 5-30 per cent. Cr. (containing also nickel, tungsten, molybdenum, etc.) constitute the stainless steels, the best known type being the 18-8, with 18 per cent. Cr. and 8 per cent. nickel. Compositions with higher chromium content are particularly useful for high temperature work in various industries. High-nickel alloys (60 to 80 per cent. Ni and 10-20 per cent. Cr.) are used as resistance elements in electrical equipment as they have high resistance and function well at high temperatures. A type of hard tool-steel having high chemical and abrasion resistance contains 30 per cent. Cr., 50-60 per cent. cobalt and the rest tungsten or molybdenum. The well known alloy called *stellite,* used in high-speed tools, contains less chromium (10-12 per cent.) and more cobalt.

Chromite is used as a refractory in basic open-hearth furnaces as it is neutral to a wide range of slags. With magnesia, lime or high refractory clay as binder it is used both in the form of a cement or as bricks (of pure chromite) in the region between the basic hearth and acid roof of the furnaces. It is refractory at high temperatures and withstands sudden changes of temperature. For this purpose the chromite should be low in iron and silica but may be high in alumina.

It is the chief raw material for the manufacture of chromium compounds like alkali chromates and dichromates, chrome-alum, etc. Lead chromate and chromic oxide are used as paint pigments while the alkali dichromates find use in the dyeing and tanning industries.

Before the War chromite containing less than 47 or 48 per cent. Cr_2O_3 and more than 15 per cent. FeO did not find a ready market but lower grades are taken now-a-days. The standard Cr : Fe ratio acceptable to manufacturers is 3 : 1. In Canada efforts have been made to beneficiate chromite by smelting it with lime.

Distribution

Three groups of deposits are known in this Province, two in Salem and one in Kistna. Only the last are being worked at present.

Kistna.—A number of small deposits have been discovered in the hills near Kondapalle (16° 37′ : 80° 32′ 30″) in and after 1937. The mineral occurs as veins, pockets and disseminated masses in pyroxenite (ultrabasic charnockite) composed mainly of enstatite-hypersthene which has partially been serpentinised. Much of the credit for discovering and developing the deposits goes to the Rajendra Mining Syndicate of Guntur (Mr. V. V. Punnaiya, Proprietor).

The main workings are near mile 2½ on the road going up from Kondapalle to the top of the hill. Here the ore is a mixture of chromite and serpentinised pyroxene. A few other small deposits have been worked in the area around this, including a vein 3-6 inches thick in a dyke of pyroxenite on the western flank of the ridge 1086. These quarries are said to have yielded some 2,000 tons of concentrates during 1941 to 1946.

A vein 4-8 inches thick (as also some connected thinner veins) was worked for a short time by the Royal Mining Syndicate of Guntur on the western flank of hill ·472 (Gangadevigutta) about 4 miles north of Kondapalle.

Some small veins found on the southernmost hillock of the hill-mass three-quarters of a mile north of Konduru (16° 40′ 30″ : 80° 34′ 30″) have been worked out, yielding only some 60 or 70 tons of ore.

A promising deposit is that of Kadımpotavaram on the border of the Reserved Forest about 4 miles N. by W. of Kondapalle. This was opened up but not worked as the ownership of the land was under dispute. It may contain a few thousand tons of good ore. Other deposits have been located amidst the hills N.W. of Kondapalle and west of Gangineni railway station. The area is covered by a thick and heavy growth of thorny bushes which makes prospecting very difficult and expensive. As the whole hill mass near Kondapalle is composed of charnockites there is a reasonable prospect of finding several, though perhaps small, deposits.

The Kondapalle ore is of two types, a hard massive ore forming veins and a comparatively soft ore which occurs as disseminated grains in serpentinised pyroxenite. The former is generally broken up and sorted after blasting or breaking up the vein material, while the latter is crushed to the size of medium grained sand and concentrated by water in a sloping platform built near the mines, in order to produce a marketable concentrate.

The following analyses give an idea of the nature of the Kondapalle ore (figures—per cent.):—

—	1	2	3	4	5
Cr_2O_3 . . .	46·16	38·80	53·6	42·6	49·5
FeO . . .	23·06	22·75	20·0	19·8	19·5
SiO_2 . . .	0·68	6·32	6·8	—	—
Al_2O_3 . . .	17·9	17·35	7·8	—	—
CaO . . .	2·65	2·66	0·2	—	—
MgO . . .	9·20	10·21	12·2	—	—

(1) Lump of high grade detrital chromite (Anal., G.S.I.)
(2) Massive ore from vein (Ditto)
(3) High grade detrital ore
(4) High grade soft ore
(5) Concentrate from soft ore
} Analyses supplied by Rajendra Mining Syndicate

Experiments on the beneficiation of the soft Kondapalle ore were made by Mr. P. I. A. Narayanan (Metallurgist in the Geological Survey of India). The results showed that tabling the minus 48 mesh product improved the Cr_2O_3 content to 49·9 per cent. (82 per cent. recovery) and flotation of 100 to 200 mesh product gave the same Cr_2O_3 percentage with 94·5 per cent. recovery. The Cr_2O_3 could be improved to 51 per cent. but at the sacrifice of recovery.

—	Original Sample (per cent.)	Table concentrate (per cent.)	Flotation concentrate (per cent.)
Cr_2O_3	44·33	49·90	49·38
SiO_2	8·28	3·32	3·44
FeO	19·33	20·36	19·74
Al_2O_3	—	16·32	—
MgO	—	10·00	—

Salem: Chalk Hills.—Some deposits of chromite have been found in association with the ultrabasic rocks (dunite) of the Chalk Hills area near Salem town, at the foot of the Shevaroys. These have yielded a small tonnage in the last Century. At present however no workable deposit is seen, though occasional fragments and small patches of disseminated ore in the altered dunite can be noticed.

The discovery of chromite in the Chalk Hills area is attributed to Mr. J. M. Heath (well known in connection with iron and steel manufacture in this Presidency in the 19th Century) who was at one time commercial Resident (Collector) at Salem in the Civil Service of the East India Company, and who was an enthusiastic prospector. In 1832, James Prinsep of Calcutta gave a description of some specimens of the mineral (chromite) sent to him by the Porto Novo Iron Co. from the mines opened by them near Karuppur (11° 43′: 78° 6′) and stated that works had been established in Salem for the preparation of bichromate of potash. Capt. T. J. Newbold visited the mines in 1840 and they had been abandoned by that time. He states that the mines were situated at Carpur (Karuppur) 4 miles N.W. of Salem, and consisted of two shafts which reached depths of 59 and 63 feet respectively. According to him the veins observed were—

"from a few lines to between 3 and 4 feet in thickness, but very irregular, contracting suddenly in some places and again expanding in others. The ore in other situations is seen in detached nodules and angular masses embedded in magnesite. One of the blocks weighed, according to the information of the miners, a couple of tons. The veins run more frequently along the sides of the magnesite veins than along their middle, but are rarely observed penetrating and intersecting them."

The thickest vein observed was 3½ feet thick and the ore was fissured, the cracks being filled with magnesite. The ore was compact, granular and assayed 49 per cent. Cr_2O_3. It is said that 100 tons were raised from here and sent by road to Mohanur on the Cauvery and thence by river to Porto Novo and shipped to Europe.

King and Foote, Holland, and Middlemiss have also described the area, in connection particularly with the magnesite deposits. Middlemiss saw thin chromite veins in some pits in the Chalk Hills area. Some of them were traceable towards the ENE for about 1,000 yards. He also mentions that in a small area (east of the Chimney then existing) from which half a dozen streams radiated, every one of those streams showed lumps of chromite of all sizes up to 1 foot across. Pieces of chromite were also found in a part of the southern area between what Middlemiss describes as "Tent Hill" and "Green Bush Hill" which, according to him, might contain chromite veins.

A small vein, 4 inches thick, was also found in association with dunite and magnesite at the N.W. base of the Kanjamalai a few miles

west of Salem. Newbold states that he was informed that chromite occurred with magnesite at Yedichicolum on the Cauvery near Trichinopoly and near Coomarpollium (Kumarapalaiyam on the Cauvery opposite Bhavani). I have not been able to identify Yedichicolum on modern maps.

Salem: Sittamundi area.—A new deposit was discovered in 1943 by Messrs. N. K. N. Aiyengar, and A. P. Subramaniam of the Geological Survey of India in the corundum belt remaining through the Tiruchengodu and Namakkal taluks. This belt extends from Pattalur (11° 16′ 30″:77° 48′ 30″) on the Cauvery, through Sittampundi (11° 15′:77° 54′ 30″), Pamandapalaiyam and Karungalpatti to Kottakkalpalaiyam (11° 16′:78° 1′) where it turns northwards and continues through Puduppalaiyam and Sayakkadupudur (11° 19′:78° 1′) to Illupuli (11° 22′:78° 1′ 30″) and beyond.

This belt consists of anorthite-gneiss, garnet-amphibolite, pyroxenite and amphibolite in a country of granite-gneiss traversed by pegmatite and quartz veins. The chromite is intimately associated with the amphibole which has been derived from pyroxenite. The amphibole is an alumina-rich variety near pargasite and there is also a rhombic amphibole. Chromite occurs in this rock as grains, stringers and thin veins. The rock shows also some corundum grains, often of red colour, especially near its contact with the anorthite gneiss, *e.g.*, near Pamandapalaiyam. The chromite is mixed with amphibole in all proportions but it is only rarely that it forms solid veins or lumps to the exclusion of the amphibole. Some lumps of chromite were found near Karungalpatti and Kottakkalpalaiyam.

Though a little chromite is generally found in the amphibolite throughout this belt, it is only in the middle part, 12 miles long, between Sittampundi and Kottakkalpalaiyam, that the mineral is found in some abundance. In this stretch there are often 3, 4 or 5 parallel bands of amphibole-chromite rock, but all within a width of about 500 yards constituting the anorthite-gneiss belt. Two bands of chromite-bearing rock, 100 feet long and 2 feet thick each are found near Sayakkadupudur; 4 short and thin bands just south of hill ·693 (north of the above village); and another small band east of Illuppuli.

Twenty-two representative samples were collected from various places in the main belt. The crude ore analysed by the Geological Survey of India gave between 18 and 31·5 per cent. Cr_2O_3 and 10 to 32·6 per cent. FeO. The average of all the samples was 25·7 per cent. Cr_2O_3 and 23·2 per cent. FeO. Three samples which were analysed for other constituents showed high alumina (24 to 30 per cent.) and 6 to 14 per cent. silica. The crude ore was concentrated by panning and by electro-magnet. Nine samples of the pure concentrates, analysed in the Madras Industries Department laboratory

(by Mr. P. T. Ramacharlu, under the direction of Dr. G. Gopal Rao) gave the following results:—

——	Minimum (per cent.)	Maximum (per cent.)	Average (per cent.)
Cr_2O_3	32·98	36·08	34·72
SiO_2	0·25	1·54	1·11
Al_2O_3	25·62	27·76	26·39
FeO	27·96	30·21	28·91
MnO	0·12	0·20	0·15
CaO	trace	0·45	0·19
MgO	5·41	10·02	8·80

A sample of the ore was also tested by Mr. P. I. A. Narayanan (for some time metallurgist in the Geological Survey of India) as to its suitability for concentration by tabling and flotation. It was found that, though the ore is amenable to concentration with a fairly high recovery, the Cr_2O_3 content could not be improved because of the high iron and alumina content of the ore.

——	Ore as received (per cent.)	Table concentrate (48–200 mesh)
Cr_2O_3	25·9	34·72
SiO_2	12·2	3·16
FeO	—	31·14
Al_2O_3	—	22·55
MgO	—	7·96
MnO	—	0·85

Specific gravity of the concentrate=4·38.

The ore is expected to be suitable for use as a refractory as two samples of crude ore which were tested softened at 1600° and 1700° C. It may be possible to beneficiate the ore by a process of smelting or chemical means, through research.

There are several old trenches and quarries along this belt which helped in the field studies. It is estimated that 220,000 tons of crude ore is available within a depth of 20 feet from the surface. There seems to be every probability of the ore persisting down to 100 feet depth

Production and Prospects

There has been a small production of chromite during the last few years from the Kistna district as shown below.

Intensive prospecting in the Kondapalle hills may bring to light some more deposits but the irregular nature of the deposits and lack of knowledge of their behaviour are factors which prevent any reliable estimate of the resources. The Salem deposits are more regular though they consist of a series of lenses confined to the anorthite-gneiss belt. They are likely to continue to some depth and to yield a few hundred thousand tons. The Salem ore appears to be useful for refractory purposes.

Production of chromite from Kistna district

Year	*Tons*
1941	170
1942	525
1943	500
1944	500
1945	—
1946	274

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CHAPTER X

CLAY

Clay is a fine grained, soft earthy material whose most important characteristic is 'plasticity'. That is to say, it can be moulded into any desired shape when moist and this shape is retained after drying. It can be made hard and permanent by firing in a kiln.

Ordinary clays consist of a number of minerals most of which are aluminium silicates, of which kaolinite is a typical member. Dickite, halloysite, beidellite and montmorillonite are also common. In addition they may contain also quartz, micaceous or sericitic material, carbonates of calcium, magnesium or iron, and hydroxides of iron or manganese.

Clay particles are very fine grained and mostly smaller than 2 μ (0·002 mm.) in diameter. They can be dispersed and suspended in water. Small quantities of electrolytes in the water make them remain in suspension (*e.g.*, sodium silicate, carbonate, hydroxide, etc.,) or may produce coagulation (*e.g.*, chloride of sodium, calcium, aluminium, etc.,) depending on the hydrogen ion concentration (pH) of the solution. Many clays also possess the property of base-exchange, *e.g.*, the replacement of an alkali or alkaline earth element by another element of these groups. This useful property has certain important industrial applications.

When examining clays, certain properties are determined qualitatively or quantitatively. There is apparently no satisfactory quantitative test for plasticity, though a relative idea can be gained after a little experience. Clays contain appreciable quantities of water a part being 'shrinkage water' (lost when dried at constant room temperature) and the rest 'pore water' (lost below 110° C.), both having influence on the plasticity. Shrinkage water is high in very fine grained compact clays yielding a strong body when dried but liable to warping and cracking. For the manufacture of good glass pots and crucibles a ratio of 1:1 between shrinkage and pore water is said to be the best. Since porous clays are easier to dry than stiff clays, the latter should be dried slowly and carefully to avoid cracks and stresses. Porous and open-textured clays are often mixed with compact clays in order to obtain a suitable degree of plasticity and shrinkage in the mixture.

The size of particles and their relative proportions is usually determined by passing the clay through sieves of different size openings. The particle size is described more or less as given below:

Coarse sand	2 to 0·25 mm
Fine sand	0·25 to 0·05 mm
Silt	0·05 to 0·005 mm
Clay	0·005 to 0·002 mm
Colloidal matter	0·002 and smaller

Clays have a large range of colour—red, brown, yellow, grey, earthy, white and black. There is often a difference in colour between a dry and wet or damp sample of the same clay and the colour may be different again after firing. The colour in fired clays is usually influenced by the iron or titanium content. Iron oxide under 1 per cent. yields white-burning clays, but one cannot predict the shade of colour of burnt clay from an inspection of chemical composition. Buff-burning clays usually contain 1 to 5 per cent. ferric oxide. Above this, the clays burn red or brown. In a reducing atmosphere, the colour may become bluish or greenish black and the temperature of burning also seems to have effect on the colour.

The fusibility of clay is important as it determines the degree of refractoriness. Clays with high iron and lime are easily fusible whereas those containing a very high proportion of kaolinic material are refractory. The process of formation of glassy material by fusion is called vitrification. Clays showing a fairly large range of temperature between the first point (incipient vitrification) and the completion of vitrification are desirable for the manufacture of vitrified wares, since the firing temperature cannot be controlled within a very narrow range in ordinary commercial kilns.

The temperature of softening of the clay during firing is usually expressed in terms of Seger Cones, each Cone number corresponding to a particular temperature (ranging from Cone 1-1150° C. to Cone 35-1785° C.).

Clays can de divided into the following groups:

Kaolins.—These are alumino-silicates derived mostly from the alteration of feldspars in granites, gneisses and pegmatites, either by weathering or hydrothermal agency. There are good deposits of kaolin in the West Coast districts where it has been formed from feldspathic gneisses capped by Tertiary sandstones and laterite. The blanketing effect of the Tertiaries seems to have influenced the formation of kaolin, and weathering has proceeded to a depth of 30-40 feet into the gneiss.

Kaolins are used after washing as fillers in textile, paper and other industries, and in the manufacture of Chinaware, white-tableware, porcelain insulators, etc.

Ball clays.—This type is a plastic refractory clay generally high in alumina, which burns practically white and is used as an ingredient of white-ware, as the bonding material in abrasives, for saggers, fire-bricks, etc. Some ball clays occur at or near the base of the Tertiaries in Travancore and Malabar.

Fire clays.—These are of sedimentary origin and refractory up to about 1300° C. They are generally plastic and are used for making

fire bricks, for lining kilns and furnaces and as a bonding medium. Fire clays often occur in conjunction with coal seams. A bed of fire-clay has been noted to occur just below the lignite in the records of boreholes put down near Vriddhachalam. Fire clays also occur in the Gondwanas, Cuddapahs and amongst some residual clays derived from the Archaeans.

Stone-ware clays.—These are semi-refractory and dense-burning clays which generally burn buff. Good stoneware clays have been got from the Cuddapahs near Rajampet.

Brick clays.—For making bricks, tiles, sewer pipes, flower pots, etc., it is possible to use any good sedimentary or residual clay or soft shale. Shales are often worked, crushed and disintegrated and left moist to weather for some time before being used. Many alluvial clays are good for this purpose. The best known clays of this type are found near Mangalore, Calicut and Quilon, where a flourishing brick and tile industry exists, as also in the river valleys of several Coastal districts.

Uses

White clays, both kaolins and sedimentary clays, are generally washed, *i.e.*, mixed with abundant water, stirred and allowed to flow as a suspension into settling tanks where it settles slowly. The settled material is then passed through filter presses. The clay cake thus obtained may be marketed after drying or mixed with water to form a fairly thick slurry which is poured into moulds to make porcelain, white-ware, dolls, etc.

Other types of clays are generally disintegrated if necessary (this applies especially to shales), dried and passed through sieves to eliminate coarser materials such as sand, nodules of lime, ironstone, etc.

After ageing the clay if necessary, by mixing it well and leaving it exposed in a moist condition to the weather, it is put through a pug mill for thorough mixing before being put to use.

Kaolins and white clays are used as filler in textile, paper, and other industries where a fine white material is required; and for the manufacture of porcelain, white ware and high grade stoneware. Non-refractory clays of light colour are used for making stoneware, terra-cotta, abrasive wheels, zinc retorts, saggers, face-brick, etc. Other refractory clays are used in the manufacture of refractories, firebricks, abrasives, glass pots and non-refractory coloured clays for making bricks, roofing and flooring tiles, flower pots, drain pipes and similar materials.

Distribution

The information given in this section is taken from recent reports on ceramic raw materials in the Province by members of the Southern Circle of the Geological Survey of India. Some preliminary work in this connection was done by Mr. M. S. Balasundaram in 1943 and a little more detailed examination undertaken by Messrs. A. P. Subramaniam and R. Thiagarajan who have examined the known deposits in several districts. Dr. Gopala Rao of the Andhra University has investigated a few deposits in Vizagapatam and Godavari districts and given us some reliable analyses. In contrast with the above, the report on ceramic survey conducted by Mr D. Sundaravelu Pillai in 1931-34 unfortunately contains some misleading information and unreliable analyses.

VIZAGAPATAM

Bennavolu hill.—This is 6 miles from Chodavaram. Some 150 feet up from the base kaolinie material is found in a few places which yields 25 per cent. white clay (kaolin) on washing, the washed clay having a slight yellowish tinge. The clay has low plasticity, does not fuse at 1250° C. and burns buff to brown.

Bhogapuram.—The hill near this village, 5 miles from Chodavaram, is said to contain an extensive deposit of gritty white clay which burns light buff with incipient vitrification at 1200° C.

Balighattam.—Two miles from Narasapatam, on the banks of the River Varahanadi and neighbouring fields, buff clay is found. It burns brown and is useful for making bricks and tiles.

Pakalapadu.—Light yellow clay is found on the banks of Varahanadi. It burns to a chocolate colour and becomes hard and vitrified. The clay can be used as polishing powder also as it is siliceous.

Yerravaram is some 5 miles from Narasapatam. In the Reserved Forest two miles from the village, decomposed pegmatite resembling cornwall stone is found. It fuses at 1250° C. yielding a snow-white opaque mass.

Dasannapeta is near Vizianagram. On the banks of a stream flowing by the Matchakonda, there occurs a gritty white clay which yields a fine plastic white clay after washing. It yields a pale yellow vitrified mass on firing at 1250° C., and should be considered a high grade ceramic material.

Similar deposits are said to occur in the following places in the same district:—

1. Kalyanalova and Malakalapalli near Kothakota on the Chodavaram—Narasapatam road.

2. Kanakapa and Rogolu near Garividi station (B. N. Rly.).

3. Vangirigedda, Jannivalasa, Chipruvalasa, Kodama and Thomam, near Salur.

4. Koraput and Nowrangpur in Jeypore Estate.

5. Pendurti and Thadi near Vizagapatam.

6. Punyagiri and other places near Sringavarapukota.

Kodur.—Pockets and lenses of a refractory clay are found in the manganese mines at this place.

Rajapalem.—The hill near this village, which is ¾ mile from Tada railway station shows exposures of good china clay. The extent is not known.

Jeypore.—A plastic clay found in the Christian street here is suitable for making bricks and tiles after mixing it with other clays. A yellow clay near the guest house and Marsh choultry can be used for making terra cotta.

Vizagapatam.—In the Government land adjoining the harbour area a layer of black clay is met with at a depth of 5 or 6 feet and is 8-10 feet thick. The clay is very plastic with practically no grit, and is dark grey in colour. This clay was sent to the Madras pencil factory through the Director of Industries, but nothing was heard from the factory regarding its suitability. The Superintending Engineer of the Circle, Rao Bahadur M. K. Ranganathan, stated that this clay occupied at least 5 acres and had an average thickness of 8 feet.

EAST GODAVARI

Kotta Bommuru (16° 58′:81° 48′).—White clays are seen in two hillocks south of this village, where they are intercalated with red grits and sandstones (Rajahmundry sandstones). Good white clay occurs at a depth of 20 feet and has been worked on the western hill. The two hills together should contain a few thousand tons of this clay. The clay is plastic and burns to slate grey colour and vitrifies at 1300° C. to a dense mass. It can be used for making chinaware and stoneware.

Punyakshetram (16° 59′:81° 51′).—Greyish white clay is won from a horizon 30 feet below surface. The overlying rock is Rajahmundry sandstone. The clay bed is said to be 10 feet thick. In the area of this village the reserves are estimated at 200,000 tons of clay. This clay is plastic and burns into a hard yellow vitrified mass at 1250° C. It is a good pipe-clay and can be used for stoneware manufacture. It can be used also as a bonding clay for making saggers.

Peddapuram (17° 5′:82° 8′ 30″).—On the slopes of the hill (·250) west of this village, white and bluish white clays are exposed at a depth of 15 feet below the Rajahmundry sandstone. The material varies from a finely laminated shale to harder shale and forms a 10-foot bed. The reserves here are of the order of 10,000 tons within a depth of 20 feet.

Jaggampeta (17° 10′:82° 4′).—About 1½ miles west of this place white clayey sandstones are seen. Quarries ½ mile south of Gurapalem expose excellent clay which amounts to about 20 per cent. in the sandstone. The reserves are large.

The clay burns white and hard and is not vitrified at 1300° C. It is suitable for making porcelain and stoneware.

WEST GODAVARI

Dwaraka-Tirumala (16° 57′:81° 15′ 30″).—The clay occurs here in the Raghavapuram shale stage and varies in quality from soft plastic clay and laminated soft shale to harder stuff. Good clay is being won from a depth of 20 feet and shows greyish white colour. The reserves are large and may amount to a million tons within 25 feet depth.

The clay is plastic and burns bluish white and hard, vitrifying at 1250° C. It is of the ball-clay type and can be used for making whiteware and stoneware.

The following table of analyses of Vizagapatam and Godavari clays has been taken from a paper by Dr. G. Gopala Rao and N. B. V. Krishna Rao.

Clays from Vizagapatam and Godavari Districts

(Analyses by G. Gopal Rao and N. B. V. Krishna Rao)

—	Benna-volu.	Bhoga-puram.	Bali-ghattam.	Pakal-padu.	Yera-varram.	Dasanna-peta.	Kodur.	Bommur.	Punya-kshetram.	Dwarka-Tirumala.	Pedda-puram.	Jaggam-peta.
SiO_2 . . .	70·91	73·22	59·23	66·32	73·87	79·16	57·89	49·73	56·05	57.36	42·62	66·90
TiO_2 . . .	0·09	0·17	0·66	0·35	0·13	0·18	2·29	1·49	3·40	1·35	0·69	0.14
Al_2O_3 . . .	16·94	15·52	17·82	13·24	16·56	13·49	29·45	34·49	28·56	27·76	39·51	23·74
Fe_2O_3 . . .	1·72	1·29	4·25	2·69	1·36	0·77	0·99	1·69	1·03	1·19	2·41	0·83
FeO . . .	0·07	0·04	0·09	0·09	0·06	—	—	0·09	0·28	0·25	0·37	0·10
MnO_2 . . .	0·88	0·05	0·24	0·60	0·66	0·49	0·13	0·05	0·06	0·01	0·10	0·05
CaO . . .	1·44	0·62	0·95	1·27	1·61	1·04	0·51	1·78	0·33	0·63	0 23	0·63
MgO . . .	0·54	0·42	1·23	1·09	0·19	0·70	0·23	1·02	Tr.	0·22	Tr.	0·27
K_2O . . .	3·05	3·55	2·38	1·36	3·18	2·62	—	0·03	0·11	0·71	0·28	0·04
Na_2O . . .	0·45	2·21	0·81	3·49	2·56	1·40	0·05	0.06	0·38	0·40	0·16	0·08
Loss . .	3·83	3·39	12·65	9·06	0·90	1·08	8·78	10·11	11·47	10·06	14·03	8·06
Moisture . . .	0·72	1·15	6·60	3·70	—	6·30	0·50	0·74	1·80	2·40	1·20	0·25
Plasticity . .	Poor	—	V. Poor.	V. Poor.	—	Good.	V. Poor.	Good.	V. Good.	V. Good.	V. Poor.	Poor.
Water of Plasticity .	40·6	—	—	—	—	38·0	—	28·0	25·7	38·0	—	33·8

GUNTUR

Macherla.—White clay has been observed near the railway station and in a well in the Inspection Bungalow close by, but the occurrences have not been investigated.

CUDDAPAH

Hastavaram (79° 7′: 14° 13′ 30″).—White clays have been worked by Messrs. Parry & Co. at the south-eastern foot of the hillocks west of Hastavaram. They have been derived from the alteration of the shales of the Cheyair Series. The material is under an overburden of 4 to 9 feet of sandy soil and is exposed in a quarry in an area of at least 150 yards × 75 yards to a depth of 45 feet. It is practically white, with a few pinkish streaks.

The clay is plastic, shows a firing shrinkage of 30 per cent. and burns to a grey colour. The reserves in an area of 500 yards × 100 yards and 30 feet depth are 900,000 tons capable of yielding 66 per cent. refined clay on washing.

Tallapaka (14° 14′: 79° 10′).—Shales are exposed in the Munikonda hills, 1 mile west of Tallapaka. In a restricted area they have weathered into soft clays. The deposits are small in extent.

Settigunta (13° 51′: 79° 24′).—Banded grey and purple shales are seen near Peddapadu, S.S.E. of Settigunta, in the Sashachalam R. F., usually at a depth of 20 feet. They are 5-6 feet thick, overlain by lateritised rock. They are refractory at 1300° C. and burn pink. The thick overburden is an obstacle to the working of these.

Kodur (13° 57′: 79° 21′).—Purple and grey shales are seen in wells at Kodur, Erraguntlakota and Reddivaripalle. They are refractory and burn to a buff colour. Pockets of white clay are seen in the stream bed near Erraguntlakota for a distance of 200 yards but the quantity is not large.

Light and dark grey clays are seen in the Mushtiyeru (river) 5½ miles S.W. of Kodur, for a distance of 175 yards. They are refractory at 1300° C. and burn light red. The reserves to a depth of 20 feet are about 100,000 tons.

Anantarazupeta (14° 0′: 79° 20′).—Weathered buff and purplish shales are seen in a stream ¾ and 1¾ mile north-east of this village. They burn to a purplish grey colour and are refractory. The amount available in the two localities are respectively 5,000 tons and 72,000 tons of good clay after allowing for the grit present. Some pockets of white clay occur in these.

Chinna Orampadu (14° 0′: 79° 16′).—Weathered grey and purple shales are seen between here and Ungareddipalle and also south of Gadela (14° 0′: 79° 14′ 30″). In the area west and north-west of △ 757 they occupy an area of 40,000 sq. yards, and the reserves here to

a depth of 5 feet, would be 120,000 tons. About 2,500 tons are estimated for the deposit in the stream bed near hill 1420, and 16,000 tons in another deposit due north of △ 757, to a depth of 20 feet. The clays show incipient vitrification at 1275° C. and burn grey to buff.

Pullampet (14° 7′: 79° 12′ 30″).—A white clay bed, 1½ to 2 feet thick, is met with at a shallow depth south of the tank of Vallurupalli. The clay is underlain by ochreous shale to a depth of 4 or 5 feet. The quantity available (of white clay) is quite small.

Chitvel (14° 10′: 79° 20′).—The plains around here are underlain by banded grey and purple shales which have been bleached in places. Weathered grey shales along the stream south of the village occupy an area of 450 feet × 40 feet and this patch would contain 7,200 tons. The material begins to vitrify at 1300° C. and burns to a brown colour.

Obali (14° 17′: 79° 13′ 30″).—About 2 miles E.N.E. of Obali and 2 furlongs S.E. of Singareddipalle, light grey, buff and white clays are exposed. They are soft and plastic and begin to vitrify at 1250° C., burning to a light purplish grey colour. In an area of 600 feet × 150 feet and 6 feet depth the reserves would be 33,000 tons.

Nandalur (14° 16′: 79° 7′).—Nearly two miles W.N.W. of *Paturu* (14° 15′ 30″: 79° 4′ 30″) is a deposit of white clay in a small valley, surrounded by flaggy shales. To the south and south-west of the white clay are exposed buff shaly clays. The reserves of white clay here are estimated at 80,000 tons and buff clay at 55,000 tons. Both vitrify slightly at 1300° C. and burn to a greyish colour.

Bhakrapeta (14° 25′: 78° 57′).—White to purplish shaly clays are seen about 3 miles W.S.W. of Bhakrapeta in a valley 2 furlongs south of a well called *Kadikona bhavi*. The white shaly clays occupy an area 150 yards × 80 yards and to a depth of 15 feet. The reserves here would be 112,000 tons. The material vitrifies at 1250° C. and burns grey to purplish, with a low shrinkage. A few hundred tons of ochreous clays are also available.

Rampatadu (14° 29′: 78° 41′ 30″).—Somewhat calcareous white clays are seen one furlong west of this place in stream sections. They are about 6 feet thick, under the soil cover. They are very plastic and become light yellow or brownish but are fused at 1250° C. The amount of clay available would be 160,000 tons in an area of 1,000 feet × 400 feet.

Porumamilla (15° 0′ 30″: 78° 59′ 30″).—Buff clays are met with on both banks of the Sagileru 2 miles west of this village, in three large patches. The reserves are estimated at a total of 42,000 tons.

Most of the clays in Cuddapah are fairly plastic and are refractory or show incipient fusion at 1250° C. They can be used for making stonewares, tiles, sewer pipes, hollow blocks, etc.

KURNOOL

Ramallakota (15° 34′: 78° 0′ 30″).—About a mile and a quarter N.N.E. of this village, the shales underlying the Pinnacled quartzite of the Kortikunta plateau are found altered to white clay containing bands and pockets of yellow ochre. The clay has been worked by a trench measuring 100 feet × 30 feet × 15 feet. The clay freed from coloured streaks and patches has been exported from here. White clays are also seen near mile 2 on the Pullagummi road. The clay resources of this area are of the order of 350,000 tons within 25 feet.

Betamcherla (15° 27′: 78° 9′).—About 3 furlongs S. S. E. of Betamcherla railway station white clay and yellow ochre occur together in purple shales of possibly Jammalamadugu age. The clay and ochre are products of alteration of shales *in situ*, and have been worked for some time. There are still several hundred tons of white clay available. The possible extension of the deposit into the hill is not known, and this can be found only by putting down boreholes. The clay is plastic, burns buff and does not vitrify at 1200° C.

Ambapuram (15° 23′: 78° 6′).—Some 2½ furlongs south of this village, white clay streaked with purple occurs sporadically with yellow ochre. Numerous pits are worked here over a length of 3 furlongs along the strike (E-W). The clay is plastic, light yellowish, and vitrifies slightly at 1200° C., becoming cream-coloured. In this deposit, which is 450 yards long and 300 feet wide, the reserves to a depth of 90 feet would be 2·2 million tons of which a small proportion would be white clay. The deposit is 3 miles from Rangapuram station.

Gani (15° 40′: 78° 19′).—Three miles to the S.E. by S. of Gani, which is 11 miles north of Panyam (Panem or Paniem) railway station is a deposit on a hill side between 750 feet and 800 feet contours in a limestone-shale formation which may be Cheyair age or younger. The shale is white with purple streaks, but the white material can be separated. The deposit was worked a few years ago and abandoned, but a few hundred tons of good clay must still be available. The white clay vitrifies slightly 1200° C. and burns buff. The average material contains about 10 per cent. grit and the washed clay is plastic and burns to a light red colour.

Giddalur (15° 22′ 30″: 78° 55′ 30″).—Half a mile S. S. W. of this place, the banks of the Sagileru expose a patch 500 yards long showing purplish and grey shales which have given rise to soft clays. The deposit contains 84,000 tons to a depth of 4 feet.

Praema (15° 30′ 30″: 78° 36′ 30″).—White clay is seen in pits half a mile south-east of this village. The quantity to a depth of 10 feet would be 450,000 tons.

Paibagala (15° 37′ : 78° 21′).—One mile N.W. of this village are pits showing good clays of white colour with purple streaks. Assuming a thickness of 11 feet for the deposit the reserves of clay would amount to 120,000 tons.

Puricherla (15° 43′ 30″ : 78° 3′).—A furlong east of this village are some workings in clay overlying quartzites but they appear to be patchy.

ANANTAPUR

Balapuram (14° 47′ : 77° 58′ 30″).—About a furlong west of this village, the Tadpatri shales have given rise to clays locally. The white clays were found to have a thickness of about 1½ feet at a depth of 4 feet from the surface. The reserves are small, perhaps 1,000 tons. The clay is white and plastic and vitrifies at 1200° C., turning to a bluish grey colour.

Uravakonda.—White clay mixed with much sand is said to be available near Uravakonda which is 18 miles from Gulapalem railway station.

NELLORE

Sultanupuram (15° 20′ : 79° 27′).—Kaolinised pegmatite is seen in the nala S.W. of this village but the clay content does not appear to be large.

Janakammapeta (15° 1′ : 79° 51′).—In the inflow channels of the tank near this village, rather gritty Gondwana clays are exposed. The clay is buff and purple and occurs in a bed 5 feet thick. In an area of 500 yards × 120 yards the reserves are estimated at 100,000 tons of crude clay from which 45,000 tons of washed clay can be got. The clay is fairly plastic and slightly micaceous. It is generally not affected by firing at 1200° C. but a few samples (presumably rich in iron) were partially fused. The colour assumed by the clay after firing is buff or light brown.

Narasapuram (14° 59′ 30″ : 79° 51′).—In an area of 500 yards by 100 yards in this village, which was investigated by pitting, it was estimated that 415,000 tons of Gondwana clay (crude) could be got which would yield 175,000 tons of washed clay.

Prabhagiripatnam (14° 27′ 30″ : 79° 45′).—China clay occurs in a small ridge north of Kistama Konda (·455) about 1 mile west of the 6th milestone on the Podalakur—Virur road. The clay is a result of alteration of a pegmatite dyke 15 feet thick which traverses quartzites along the strike (N-S). There is an open-cast working 150 feet long and 50 feet deep. Some adits have been driven across the strike and the removal of clay has resulted in the collapse of the roof at several places.

Vadlapudi (14° 18′ 30″ : 79° 48′).—The Saraswati clay mine is situated on a ridge of quartzite just east of mile 9½ on the Podalakur—Manubolu road. The mode of occurrence is similar to that of Prabhagiripatnam, the kaolinised rock traversing quartzites which strike N-S and dip towards the west. The kaolinised pegmatite is 12 feet wide of which 3 feet is good china clay the rest being a mixture of kaolin, partly altered feldspar and quartz. In 1945 the mine was producing about 15 tons of crude clay per month. The reserves in this are smaller than in the Prabhagiripatnam deposit.

Kasumuru.—Just southeast of hill 271 about 1 mile S.S.W. of Kasumuru (a few miles N.N.W. of Gudur) is an old opencast which is said to have measured 90 feet × 60 feet × 50 feet. A kaolinised pegmatite 10 feet thick is noticed traversing the foliation planes of quartzites striking N.N.E.-S.S.W. with westerly dip. The clay content of the upper part of the pegmatite is about 25 per cent. but poorer lower down. Most of the good clay has already been removed so that the deposit is now of little importance.

A few pegmatites near Prabhagiripatnam, Tatiparti, Battulapalle Nallapalem, etc., contain pockets of china clay but these will not yield any useful quantity.

Vobulayapalle (79° 39′ : 14° 32′).—Plastic clay occurs at a depth of 3 feet south of the tank N.N.E. of this village. The clay is derived from kaolinised schists which are said to extend to a depth of at least 25-30 feet. The clay content of the rock is 40-50 per cent. and appreciable reserves can be expected. The clay resists fusion at 1250° C. and burns to a light yellow-brown colour.

NORTH ARCOT

The following occurrences in this district have been recorded by Mr. D. S. Pillai :—

White clay obtained in the neighbourhood is used for manufacture of glazed pottery at Karigeri, 4 miles from Katpadi.

White clay occurs at a depth of 8 feet at Pappantangal 8 miles north of Tiruvattur on the Wandiwash—Arcot road. Yellow to slate-grey clay is said to be found 10 feet below ground level at Dusi, 4 miles from Conjeevaram. A bed of white clay 9 feet thick is also reported to occur 20 feet below the surface at Pallur in the Arkonam taluk. White and grey clays of Gondwana age are known also to occur in other places in the Arkonam taluk, connecting up with the similar formations in the Sriperumbudur—Tiruvallur area in Chingleput.

CHINGLEPUT

The clays in this district belong mostly to the Upper Gondwana formations. In general, deposits to the north of Sriperumbudur yield soft clays while those to the south are shaly, splintery and porcellanoid.

It may be mentioned here that for the deposits in Chingleput described below, *it is assumed that the deposits are 15 feet thick and contain 20 per cent. fine clay (when washed). The reserves are given in terms of refined clay content.*

Vaiyapur (12° 52′ 30″: 79° 56′ 30″).—Thin beds of grey plastic clay are noticed at intervals along the Walajabad-Vandalur road near mile 10/3. The same type of material is seen 3 furlongs S.W. of the village in the high ground area where the reserves are estimated at 200.000 tons. The clay is plastic, and burns to light grey colour and is semi refractory.

Vallakkottai (12° 53′: 79° 56′).—Buff shaly clays are present in this village and especially in a hillock 5 furlongs to its west-south-west. The hill contains soft clay along its western and south-eastern margins. The shales are partly porcellanoid white and partly buff, the latter often bleached on exposure. The shales are very abundant. The quantity of clay has not been estimated as expensive prospecting would have to be undertaken. The clays are open-burning and show incipient fusion at 1300° C.

Vallam (12° 53′ 30″: 79° 56′).—Grey shales with pockets of good plastic clay are found to extend from this village E.S.E.-ward to Eraiyur over a length of a mile and a width of about 1 furlong, as seen in well sections. At a conservative estimate, an area of ¼ sq. mile should contain about 1 million tons. It is similar to the semi-refractory clays mentioned above.

Tattanur—Gunduperumbedu—Alagur.—White shales are seen in several places south of Tattanur (12° 54′ 30″: 79° 57′). Porcellanoid shales occur in the knoll 6 furlongs north-west of Gunduperumbedu (12° 55′: 79° 58′ 30″). Between here and Alagur (12° 54′ 30″: 79° 59′ 30″) and also east of Alagur, compact shales are exposed over an area of 1 mile by 2 furlongs. If this area contains an average of 3 feet thickness of soft shales the available reserves would be 1 million tons. The material is semi-refractory and burns buff.

Sriperumbudur (12° 58′: 79° 57′).—White and buff coloured shales (locally known as *sheeka-parai* or soapnut rock) are found in and around this small town after which one of the divisions of Upper Gondwanas is named. The shales are rather hard but have given rise to clays which are seen N.N.W. of the Sriperumbudur tank and S.S.W. of Ayakulattur. In this area the reserves of soft shaly clays would amount to perhaps 10,000 tons.

A somewhat gritty plastic clay is seen just south-east of the Sriperumbudur tank from which 20,000 tons of (refined) clay would be available within a depth of 15 feet.

Kannantangal (12° 58′: 79° 49′).—In the area amidst the closely spaced villages of Kannantangal, Kommantangal, Gunakarambakkam and Ettikuttumedu, a light grey plastic clay occurs below a thin cover of lateritic gravel and has been worked in the first-named place. In an area of 1 mile by 2 furlongs occupied by this clay, the reserves would be 1 million tons to a depth of 15 feet. The clay is semi-refractory and burns to a light grey colour.

Mappedu-Kilachcheri.—Some old pits at Mappedu (13° 2′: 79° 52′) reveal the existence of good plastic clays southwest of the village temple. They extend southwards for 4 furlongs and pass under laterite. Westwards they extend to Kilachcheri. They cover an area of about 1½ miles × 1 mile which is estimated to contain 6·3 million tons within a depth of 15 feet from the surface. The clays are open-burning, semi-refractory and acquire a grey colour after burning.

Arivattur (13° 6′: 79° 53′)—*Vengattur* (13° 6′: 79° 56′).—Clays are found below lateritic gravel south of the Cooum river and of the village. They appear to extend eastwards to Vengattur and south-eastwards to Pakkupettai but have an overburden 15 to 20 feet thick. In the Ariyattur area where they are near the surface, an area of 600 yards × 100 yards would contain 80,000 tons. The clays burn to a pearl grey colour and are refractory.

Krishnapuram (13° 14′: 79° 52′ 30″).—Near mile 35/6 on the Tiruvallur-Nagalapuram road and not far from Pundi reservoir, shaly clays are found beneath the laterite and cover an area of at least 1½ sq. miles to the west of the road and north of the Kortalaiyar river. This area would yield a minimum of 6·3 million tons. The clays are refractory.

A white, poorly plastic shaly clay was noticed in an excavation for the foundation of the regulator at Pundi at a depth of about 20 to 30 feet. Its extent is not known. The clay disintegrates when put in water.

Clays are known to occur also at depths of more than 15 feet at Devandavakkam (13° 15′: 79° 55′), Somadevapattu (13° 14′: 79° 56′), Neyveli (13° 12′ 30″: 79° 54′), Ramatandalam (13° 12′: 79° 55′) and other places.

Koppur (13° 4′ 30″: 79° 58′).—Clays are exposed under lateritic gravels in gulleys in the Moyyar Reserved Forest which was being levelled down by excavators (1946). White clays are noticed near the bank of the Cooum river 1 mile south of Perumalpatti. At least half a sq. mile of the Koppur area contains good clays, which would amount to 2 million tons. The clays are refractory and burn to a grey colour.

Palanjur (13° 1′: 80° 2′ 30″).—Clays intercalated with sandstones are exposed along the supply channels of the Chembarambakkam tank, just south of the Madras—Sriperumbudur road. The clays are plastic but fuse at a little over 1000° C.

Tirumullaivayal (13° 8′: 80° 8′).—This is between Avadi and Ambattur railway stations. White shaly clay associated with sandstone occurs at a depth of 10-15 feet below the ground. The clay burns light buff and is semi-refractory. Its extent is not known.

Ambattur (13° 7′: 80° 9′ 30″).—Light grey Gondwana shale occurs on either side of the railway line, intercalated as thin bands with sandstones under a cover of 6 feet of lateritised material. Shaly clay is also noticed in wells in Venkatapuram colony nearby at a depth of 15 feet. So far as known at present, the clay bed may extend over a minimum area 5 furlongs long and 2 furlongs wide. The reserves in this area amount nearly to 2 million tons of crude clay.

The white clay (2 furlongs N.W. of the Railway Station) is refractory and burns white, while the other types vitrify at 1200° C. to 1250° C.

Avadi (13° 7′: 80° 6′).—In a railway cutting near this station buff clay is seen intercalated with sandstone below a capping of laterite. The area is worth investigation.

SOUTH ARCOT

All the deposits investigated in this district are in the Tertiaries. Only one, in the Kumalampattu R. F., near Brahmadesam, appears to be due to alteration of the gneiss underlying the Tertiaries. The estimates of clay given below refer to the clay content, *i.e.*, refined clay in the deposits.

Pannikuppam (11° 45′: 79° 32′ 30″).—South of Panruti and just south of the Gadilam River, white clay is exposed in deep ravines below an overburden of 35 feet of sandstones and grits. The clays are up to 10 feet thick and are overlain by sandstones. The bed appears to be irregular but extensive. A reserve of 20,000 tons may be safely taken in the area cut up by ravines and in the neighbourhood. The clay burns to a pale grey colour and is refractory. The shrinkage is high (40 per cent.).

Siranguppam (11° 45′: 79° 34′).—White clays are exposed in a ravine west of the village and in a nala to the south, under an overburden of 35 feet. In the northern area a reserve of 2,000 tons may be expected. The clay is similar to the Pannikuppam material.

Melmambattu (11° 43′: 79° 34′).—Half a mile north of the village white clays are seen below a thickness of 25 feet of sandstones, in a ravine over a distance of 100 yards. In the area immediately bordering the ravine, a quantity of at least 2,000 tons may be expected.

Maligambattu (11° 44′ : 79° 31′ 30″).—Half a mile south of the village a large ravine exposes clays for a distance of 200 yards at a depth of 25 to 30 feet. Wells in the neighbouring village of Talambattu show good clay at a depth of 50 feet. In the ravine area at least 3,000 tons of good clay will be available.

Palaiyam (11° 43′ 30″ : 79° 37′ 30″).—In the nala ½ mile west of hill ·200 and south of Palaiyam, a bed of clay is exposed while a similar exposure is seen on the eastern slope of the high ground south of Vanamdevi (11° 43′ 45″ : 79° 40′).

Tiruvendipuram (11° 45′ : 79° 42′ 30″).—On the slope of the hill which faces the Gadilam river here a bed of clay is seen intercalated with sandstone, the clay being 4 to 10 feet thick under an overburden which is upwards of 15 feet. The exposure on the slope can be followed for a furlong or so. The exposed bed would yield at least 13,000 tons, but the deposit would be really much larger.

Capper Quarry.—Similar clay is exposed in the hills near Capper Quarry which is a Railway Station near Cuddalore.

Putturai (11° 58′ : 79° 45′ 30″).—A boring put down here by a French firm in 1929 is said to have revealed a 30-foot bed of clay below an overburden of 15 feet of Tertiary sandstone. In the nalas nearby, a 5-foot bed of clay can be seen.

Near Manaveli the bottom of the Tertiaries reveal gritty clays of bluish grey to buff colour. Clays are seen also below the sandstones in the 'bad land' area west and southwest of the old Customs post of Murattandichavadi.

Tiruvakkarai (12° 2′ : 79° 39′ 30″).—White clays are seen in the fields south of the village and just west of the cart track to Eraiyur. The clay bed here is 5 feet thick. Further south also, on the banks of the Varahanadi, white clays are seen which are 7 to 10 feet thick below the soil cap. These continue eastwards. The reserves in the neighbourhood of Tiruvakkarai are of the order of half a million tons within 10 feet of the surface. The clays are refractory and burn buff or grey.

Kumalampattu (12° 8′ 30″ : 79° 47′ 30″).—White to light coloured clay occurs in the Reserved Forest near this village and is being quarried near its southwestern boundary. In a pit put down by Messrs. Parry & Co. just outside the north-eastern boundary, milk-white clay has been got at a depth of 25 feet to 35 feet.

The forest area is covered by a thin cap of Tertiary sandstone, but charnockites and gneisses, kaolinised on the surface, are exposed in some *nalas* along the western and north-western margins. Clays are exposed in some wells in the village of Adasal also.

In the area where the clay is mined, it is seen at a depth of 15 to 20 feet below the sandstone and soil. The clay burns to a nearly white colour and is refractory. It is now being used by a factory at Tiruvallur (Trivellore) near Madras for making tableware, stoneware, etc.

The area occupied by the clays may be 4-5 sq. miles. In the area where quarrying has been done (half a square mile) the amount of crude clay available, assuming a 20-foot thickness, would be at least 3·5 million tons. The deposits are only 12 to 15 miles from Tindivanam on the South Indian Railway.

TRICHINOPOLY

Gondwana clay.—There are small areas of Upper Gondwanas ex-Uttattur Stage of the Trichinopoly Cretaceous forming a N.N.E.-S.S.W. strip running parallel to the Madras-Trichinopoly road east of Perambalur. This clay is known to continue to about 100 feet depth below which a black clay is said to have been encountered in bore-holes. This yellow clay is saline in many places and is traversed by veins of gypsum. It is plastic and fuses to a dark grey mass at about 1100° C.

Gondwana clay.—There are small areas of Upper Gondwanas exposed near Karai, Terani and Uttattur. About ¾ mile east of Karai a patch of white clay is seen at the junction of the Gondwanas and Cretaceous. The clay bed is at least 10 feet thick and may occupy an area of a few acres. It is used locally for making pottery. The clay is not fused at 1300° C. and burns to a cream colour. Analyses of the Cretaceous and Gondwana clays as also that of a Gondwana shale from the Sriperumbudur area are given below:—

—	A	B	C
	(per cent.)	(per cent.)	(per cent.)
SiO_2	44·63	49·82	92·26
Al_2O_3	17·85	32·67	1·26
Fe_2O_3	7·85	1·98	0·80
MnO	0·04	—	—
CaO	3·89	0·13	1·04
MgO	2·40	0·09	0·73
K_2O	1·22	0·62	0·12
Na_2O	1·25	0·49	0·13
H_2O-	17·86	14·18	1·57
H_2O+	2·90	0·22	1·86
Total	99·99	100·20	99·77

A. Cretaceous clay 2 miles east of Karai (G. S. I. Lab.).
B. Gondwana clay, 6 furlongs east of Karai (G. S. I. Lab.).
C. Porcellanic shale, Alagur, Chingleput district. (Agr. Chemist, Coimbatore.)

MALABAR

Karivellur (12° 11′: 75° 12′).—Poor grade china clay is seen in some wells in this neighbourhood. It has been mined formerly in the high ground south of the village. Similar clay occurs also at Vellur a couple of miles to the south.

Cheruthazam (12° 4′: 75° 16′ 30″).—Along the southwest margin of hillock ·143 southeast of Elimala Railway station, china clay has been mined. The washed clay is refractory at 1350° C. and burns to a light buff colour.

Madayi (12° 2′: 75° 15′ 30″).—About 1 mile W. N. W. of Palayangadi railway station, a large quarry has been opened at the southern edge of the high ground ·134 north of the railway. This material is refractory and burns white.

Ezhom (12° 2′ 30″: 75° 17′ 30″).—Two furlongs west of Palayangadi ferry, half a mile E.N.E. of the railway station, china clay was quarried between 1941 and 1945, the total production being 1,200 tons. The quarry was not being worked early in 1947.

Kannapuram (11° 59′: 75° 19′).—A pit is being worked (in 1947) on the southern slopes of the hillock E.S.E. of the railway station, the overburden above the clay being nearly 40 feet thick. The production of china clay during 1941-46 was 1387 tons, but it has been increased to around 60 tons of washed clay per month in 1947. It is a good refractory clay suitable for making china ware.

Tiruchembram (12° 2′: 75° 21′ 30″).—China clay has been noticed to occur in this village as also at Adicheri nearby.

SOUTH KANARA

Indications of china clay are found below the laterite near Mangalore (12° 51′ 30″: 74° 50′) at Urwa, Kodial Bail and Kadri glen which should be proved by boreholes.

Bayar (12° 41′ 30″: 75° 2′).—Cream coloured clays are found in a cavern called ' Posuda gumpe ' about 9 miles east of Mangalapadi railway station. The clay vitrifies at 1350° C. and burns buff.

Mangalapadi R. S. (12° 40′: 74° 54′ 30″).—At Uppala, Mulipja and Kodibail near this place china clay rock is seen in some of the new wells. The clay is refractory and burns dirty white.

Stained and coloured clays are found beneath the laterite at and around Kasaragod (12° 30′: 75° 0′), Boyikan (12° 30′: 75° 5′), Muliyar (12° 30′ 30″ : 75° 7′) and Paika (12° 27′ : 75° 2′ 30″). They vitrify at 1300° C. burning to shades of brown.

At Ajanur (12° 20′: 75° 6′), Bare (12° 27′: 75° 2′ 30″) and Madikai china clay is noticed in well sections. It was mined formerly at

Madikai. Indications of good china clay are observed around Nileshwar (12° 15′:75° 8′), Kinanur (12° 18′:75° 12′), Kodakkat (12° 12′:75° 12′) and Charvattur (12° 13′:75° 9′ 30″).

Pudukai (12° 17′:75° 8′).—A hillock on the north-east bank of 'Monachi hole' and 3 furlongs from the railway bridge is being worked by the Hindustan China Clay Works. The clay occurs at a depth of 50-60 feet below the surface, underneath laterite. The crude clay which is washed near the mine, yields 50 per cent. fine clay, the monthly production being about 75 tons. The clay is refractory and burns to ivory white colour. It is largely used by the textile mills in Bombay. The production in 1944-45 and 1945-46 was 398 tons and 267 tons respectively. There is a large area of ordinary brick and tile clays along the banks of rivers near Mangalore, Calicut, Quilon and other places where a flourishing tile industry has been built up. These were not examined by the Geological Survey.

The preliminary survey in Malabar and South Kanara has shown that there are china clay deposits underneath the laterite in many places which will have to be investigated by boreholes. The clay is of excellent quality in general.

ANALYSES OF CLAYS OF MALABAR AND SOUTH KANARA

No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Alk	TiO_2	MnO	SO_3	Ign Loss	Total
1	44·30	38·71	0·79	0·11	Tr.	Tr.	2·10	Tr.	0·07	13·69	99·77
2	65·84	23·51	1·19	0·39	Tr.	Tr.	Tr.	Tr.	0·19	8·64	99·76
3	51·34	31·21	1·59	0·32	Tr.	Tr.	2·30	Tr.	Tr.	12·98	99·74
4	42·20	35·84	1·99	0·43	Tr.	Tr.	3·51	Tr.	0·21	15·60	99·84
5	70·24	20·81	1·49	0·23	Tr.	Tr.	Tr.	Tr.	Tr.	7·04	99·81
6	68·78	22·11	0·79	0·36	Tr.	Tr.	Tr.	Tr.	0·06	7·74	99·84
7	44·56	38·01	0·79	0·79	1·57	0·08	—	—	—	14·20	100
8	46·12	39·25	0·36	0·70	Tr.	0·10	—	—	—	13·37	100
9	43·84	29·67	3·18	0·36	Tr.	Tr.	4·05	Tr.	1·54	17·08	99·72
10	54·69	30·65	1·07	0·32	Tr	Tr.	1·30	Tr.	0·09	11·82	99·89
11	41·44	34·95	5·57	0·20	Tr.	Tr.	4·04	Tr.	0·08	13·36	99·64
12	54·28	27·83	1·75	0·29	Tr.	Tr.	0·50	Tr.	1·12	14·14	99.91
13	65·06	23·18	1·27	0·22	Tr.	Tr.	0·95	Tr.	0·26	8·86	99·80
14	43·16	31·33	4·62	2·31	Tr.	Tr.	3·18	Tr.	0·39	14·74	99·73
15	40·32	38·21	2·39	0·43	Tr.	Tr.	3·50	Tr.	0·22	14·58	99·65
16	45·56	39·81	0·37	0·41	Tr.	0·05	—	—	—	13·80	100

1. Trial pit, Vellur.	
2. Old quarry, Madayi.	
3. Old quarry, Palayangadi.	
4. Old quarry, Cheruthazham.	
5. Working pit, Kannapuram.	
6. Working pit, Tiruchchembram.	
7. Working pits, Kannapuram	Anal by Hughes and Davis, Bombay Kindly supplied by Mr. S. Aaron.
8. Working pit, Palayangadi	
9. Well in R.S. 120, Uppala	Anal by G. S. I. Laboratory, Calcutta.
10. Well in R.S. 80, Bare	
11. S.E. of Bendichal	
12. Near Tekkila—Panthadi road	
13. Hindusthan China Clay Works	
14. Greenish clay from the above	
15. Well in Ayanur	
16. Hindusthan China Clay Works	Anal by Hughes and Davis, Bombay.

TRAVANCORE

Large deposits of china clay occur near Kundara and continue southward to Varkala and beyond towards Trivandrum. The china clay rock occurs below a thickness of laterite and Tertiary sandstone which occupy the surface and may be up to 100 feet thick. The Tertiaries contain some clay and ochre beds and there is often a bed of ball clay and refractory white clay at the bottom of the Tertiaries. The garnetiferous gneiss which occurs below the sandstone has been converted into china clay rock to a thickness of 30 or 35 feet below which it grades rapidly into fresh rock. The upper portion of the china clay rock is somewhat stained but some 10 feet below the Tertiaries it is unstained. The average yield of washed china clay in the 30 foot section is roughly 25 per cent. of the china clay rock. Each square mile of the china clay area would yield 14 million tons of refined clay. Since the Tertiary sandstones are known to be underlain by kaolin at widely separated localities, the probability is that this type of clay occurs over an area of several square miles, so that the kaolin resources of Travancore may run into a few hundred million tons. The base of the Tertiaries often contains a few feet thickness of ball clay, while layers of ferruginous clay also occur within the Tertiary sandstones. A typical vertical section is as below:—

Soil	0-6 ft.
Laterite	10-20 ft.
Tertiaries	Up to 100 ft. (variable).
Ball clay	0-8 ft.
China clay rock (grading down into gneiss)	20-35 ft.

ANALYSES OF KUNDARA CLAYS

—	1	2	3	4
SiO_2	48·40	54·39	45·54	46·03
TiO_2	00·85	0·96	0·32	0·31
Al_2O_3	37·05	29·40	38·99	39·37
Fe_2O_3	0·30	2·44	0·25	0·41
CaO	0·16	0·35	0·08	Tr.
MgO	0.01	0·14	0·01	0·37
K_2O	nil	1·96	0·16	0·30
Na_2O	nil	0·03	0·10	—
Loss	13·40	10·06	14·22	13·23

1. Fire—clay from a bed at the bottom of the Tertiaries.
2. Light bluish white ball clay from just above 1.

3, 4. Washed china clay from the china clay rock.

Analyses Nos. 1-3 by North Staffordshire Technical College, England, and No. 4 by Government Test House, Alipore, Calcutta.

Prospects

Ordinary brick and tile clays are widely distributed and can be obtained from river alluvia, soil cap, tank beds, etc. Refractory clays are more restricted in distribution but are found at a number of places in the Cuddapah basin, Upper Gondwanas and Tertiaries and occasionally in the areas occupied by the Archaeans. There seem to be extensive areas of kaolin under the Tertiaries of the Western Coast and it does not appear that similar material is found in the eastern coastal districts. Occasional patches of kaolin are also found amidst the Archaeans as a result of the alteration of feldspar-rich patches.

In view of the value of kaolin as a filler and ceramic material, it is necessary to take special precautions in the West Coast against wastage because of the high rainfall and the cover of ferruginous Tertiary beds above the clay beds.

There is much scope for the expansion and improvement of the clay industries in this Province so that the market may be supplied with articles of standard quality—whether these are ordinary bricks and tiles, or sanitary ware, stoneware, pipes, etc. Since there are abundant resources in the Ceded districts, South Arcot, Malabar and Kanara, attention may be given to the establishment of factories near the deposits.

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CHAPTER XI

COAL

Coal is the most important fuel and source of heat and power for industrial purposes. It is formed by the accumulation and deposition in shallow water of vegetable matter in large quantities and the subsequent carbonisation of this material under cover of clayey and sandy sediments. The degree of carbonisation depends to a large extent on the age of the strata, the degree of compaction and the effect of pressure to which the strata have been subjected. The most carbonised variety is anthracite with very little volatile matter while at the other end is lignite which contains much moisture and volatile matter, the intermediate stages being represented by bituminous coals.

Indian coal from the Gondwana strata are generally high in ash, this varying from 10 to 20 per cent, in commercial grades. The calorific value varies from 6000 to 7000 calories (10,800 to 12,600 B.T.U.).

Uses

Coal is used primarily for the generation of heat for industrial and domestic purposes, and for the generation of power. It may be used in the raw state or converted into coke, the latter being a product left after the volatiles are driven out. The byproducts recovered during the carbonisation process in industrial plants are nowdays the basis of a large number of industries producing medicines, dyes, explosives, perfumes, etc. These byproduct industries have not yet been established in India on a firm footing but a fair tonnage of hard coke is manufactured for metallurgical purposes in which certain byproducts such as benzol, ammonia, naphthalene and tar are recovered.

Distribution

The only region in which coal has been found in the Province of Madras, though not so far in workable quantities, is the Godavari valley, on either side of the river. The following is a summarised account of the investigations carried out, the details of which can be gathered from the references cited.

LINGALA

Fragments of coal were first noticed by P. W. Wall in 1857 in the bed of the Godavari river near Lingala (18° 0′ 30″ : 80° 50′) near the junction of the Godavari and the Talperu. About a decade later, Dr. W. T. Blanford, who was working in this region, found Lower Gondwana rocks, and under his instructions a search was instituted which resulted in the discovery of four seams concealed in the sands of the river bed. Two of these, each less than two feet thick, occurred close to the left bank of the Godavari opposite Lingala, dipping south-west towards the centre of the river; the third seam 5 feet thick, was

found in the middle of the river, the sandstone associated with it striking into Hyderabad across the river; the fourth seam, found near the right bank, was 2 feet thick. All these could be traced only for a few yards in the river bed itself. No serious work was done here then or later to try and trace the seams systematically.

In 1891 the Godavari Coal Co. put down a trial pit to a depth of 11 feet on the Madras side near Lingala and raised 70 tons of coal of good quality from a 5-foot seam. But nothing further seems to have been done here.

The area was recently mapped by Messrs. V. Subramanyam and S. N. Sen of the Geological Survey of India in 1944. They found an exposure of a thin seam of coal in a reef of sandstone-conglomerate in the river close to the river bank a little to the west of Mummidivaram (hamlet south of Lingala). When this reef was opened up by a trench, two 1-foot seams were discovered. In another pit close by, three seams, 4 inches, 6 inches and 9 inches thick respectively, were found. It was not possible to follow them up for want of pumps and other appliances. The coal from the above mentioned seams was of poor quality as the ash ranged from 26 to 42 per cent.

GAVIRIDEVIPETA

Gaviridevipeta (17° 37′ 30″ : 81° 5′) is a small village some 15 miles E.S.E. of Bhadrachalam on the road to Kunavaram and lies in the midst of a field, 10 sq. miles in extent, of Lower Gondwana rocks. It is part of a much larger area which stretches across the river into Hyderabad. The field occupies a bend in the river, the northern limit running close to and parallel with the road.

Several boreholes were put down near Totapalle (17° 37′ 30″ : 81° 3′ 40″) in this area in 1870-71 on the suggestion of W. T. Blanford, under the supervision of Mr. Vanstavern of the Madras P.W.D. These showed the presence of a number of thin seams of an aggregate thickness of 10 feet 6 inches intercalated with 12 feet of shales. Some boreholes put down near the river bank indicated that a few of these coalesced to make thicker seams and indeed, a seam 18 feet thick is said to have been pierced in one borehole.

The Godavari Coal Co. conducted mining in this area between 1890 and 1895 and raised 3657 tons of fair quality coal suitable for steam raising. It is reported that mining ceased when the seam was cut off by a fault beyond which it could not be traced.

Apparently only a small area near Totapalle has been investigated. The whole field, including the western part which does not seem to have been investigated so far, should be explored by drill holes reaching down to the base of the Barakar rocks, as the possibilities of finding workable coal appears to be fair.

DAMERCHERLA—MADHAVARAM AREA

On the right bank of the Godavari in Hyderabad, opposite the Gaviridevipeta area, a few sq. miles of Barakar rocks are exposed and beyond it is an area of Kamthis. Six shallow boreholes were put down here in 1871, which indicated the presence of thin seams of coal in the Barakar strata (Blanford, *Rec. Geol. Surv. Ind.* VI, p. 61). One of these boreholes, 193½ feet deep, just east of Madhavaram, showed an upper seam of shale and coal (6 inches thick) at 45½ feet, and a lower seam 8 inches thick at 157 feet. In 1874 Messrs. Heenan and Taylor examined this area and put down borings in an area of Kamthis 3 miles from Raigudem and 5 miles south of the Godavari. Three seams were discovered, the first at 247 feet (1 foot thick), the second at 272 feet (4 feet thick) and the third at 314 feet (6 feet thick). The quality of the coal is said to have been inferior ("Coal in the Deccan" by Heenan and Taylor. Report No. 160, Coalfields Branch, H.E.H. the Nizam's Public Works Department).

A very recent boring, put down by the Nizam's Government at Timmapeta in this region is said to have struck an 1 foot seam within a depth of 250 feet. This is probably to be correlated with the top seam in Heenan and Taylor's boring. These data are interesting in that they strengthen the possibility of finding workable coal in the Gaviridevipeta area which is an extension of these rocks on the Madras side.

BEDADANURU

Rocks of Barakar facies were discovered in and around Bedadanuru (17° 14′ 30″:81° 14′) in the Polavaram Agency of the West Godavari district by W. T. Blanford and confirmed by King soon after. Exposures are infrequent and those available do not show any traces of coal or plant fossils. King's map of the area (*Rec. Geol. Surv. Ind.*, XV, p. 206) was found to be essentially correct, when the area was re-mapped in 1942 by the present writer and Mr. R. N. P. Arogyaswamy.

The Barakar rocks here occupy an area of about 6 sq. miles and directly overlie the metamorphics on the east. They dip towards the W.S.W. or west at about 10° or 12°. To the north, west and south, they are covered over by sandstones of Kamthi age (Chintalpudi Sandstones) which continue for some distance towards Ellore in the south and towards Ashwaraopeta in Hyderabad in the west.

The distinction between the Barakar and Kamthi sandstones exposed in this area, as elsewhere in the Godavari valley for some distance further up, is difficult as both are light buff or brownish in colour. From data obtained from boreholes it would appear that the Kamthis are comparatively thin—only about 200 feet thick so far as known.

Sixteen boreholes were put down near Bedadanuru between 1874 and 1876 for Government by Mr. Vanstavern (Executive Engineer, Godavari division) under the supervision of Dr. W. King of the Geological Survey of India. The boreholes ranged in depth between 193 and 356 feet, and much difficulty was encountered because of soft clays and rising sands. The logs of only 4 boreholes have been published (King: *Rec. Geol. Surv. Ind.*, XV, p. 202-207) but those of some other boreholes are given in a report published by the Government of Madras as G.O. No. 2556, P.W.D., dated 25-9-1876. The boreholes are said to have been arranged along three parallel lines perpendicular to the assumed dip direction, W.S.W.).

King states that six seams were met with, generally of too poor a quality to be worth using as fuel. The best amongst them was one 4½ feet thick, at a depth of 187·5 feet in borehole No. 4 which was situated about 2 furlongs S.W. of Bedadanuru village. This gave on analyses 12·8 per cent. moisture, 28 per cent. volatile matter, 37 per cent. fixed carbon and 25·2 per cent. ash. The total thickness of the Barakars pierced amounted to 600 feet. Since King thought that the Kamthis were likely to be thick in the area to the west, further work was discontinued.

In 1900, a company named *the Ellore Syndicate* put down 5 boreholes in the same area, evidently for the Madras Railway Company. One of these, located close to King's borehole No. 4, penetrated to a depth of 364 feet while another, located about a mile to its northwest, reached a depth of 500 feet. These did not meet with any seam, except for some streaks of coal and an 1-inch thick layer.

During the War, at the request of the Government of Madras, the Geological Survey mapped the area around Bedadanuru in 1942 and also put down two boreholes near that village. Unfortunately, the drill used was not suited to depths of more 350 feet, and difficulty was also experienced with soft strata. Four seams of coal, ranging from 4 inches to 12 inches in thickness were encountered, as also a shale-coal bed 10 feet in thickness, but no workable seam.

In 1922-23, the Hyderabad (Deccan) Co. (Managing Agents—Messrs. Best & Co. Ltd.) sank 4 boreholes in the neighbourhood of Swarnavarigudem (17° 9′:81° 14′) about 8 miles south of Bedadanuru. Three of the boreholes were located along the direction of dip (S. 60° W.), and these were estimated to have pierced a thickness of 1500 feet of Barakar strata. The dip was deduced to be about 1 in 6. A coal seam intercalated with much shale partings, of a total thickness of 10 feet 6 inches, was met in two of the boreholes, at depths of 220 feet and 818 feet respectively, but the coal was of very poor quality. The Kamthis overlying the Barakars here are only about 150 feet thick. There are no Talchirs beneath the Barakars which lie directly on the gneiss.

The borehole put down so far near Bedadanuru and Swarnavarigudem have not revealed any workable seams of coal. Though the outlook for further prospecting is not encouraging, it should be realised that only a small area (a few square miles) has been investigated and the strata stretch for several miles towards the west in the dip direction where possibly there may be some useful seams within workable depths.

YERNAGUDEM (KOVVUR) TALUK

Some prospecting work has also been done by means of boreholes in the area near and east of Koyyalagudem (17° 8′:81° 26′). The Hyderabad (Deccan) Co. put down a hole in 1922 at a locality about 1½ miles N.W. of Koyyalagudem, reaching down to a depth of 695 feet. The upper 230 feet of this was diagonised to belong to the Kamthis and the rest to the Barakars. The latter, however, did not show anything except for some carbonaceous sandstones and shales.

In the early years of the century, in 1902 and 1903, the Southern India Mining Syndicate (Managing Agents—Shaw, Wallace & Co. Ltd.) put down 4 or 5 boreholes near Venkatayapalem (17° 5′ 20″:81° 36′ 40″) in one of which, 425 feet deep, thick beds of carbonaceous shale were encountered, with thin seams or streaks of coaly material. Mr. C. S. Middlemiss of the Geological Survey of India was sent down in 1904 to examine the area at the request of the Madras Railway Co. who were interested in the investigation. Mr. Middlemiss found that the strata passed through belonged to the Kamthis which occupy a large stretch of country here and are covered in the east and south by Upper Gondwana formations. He gave as his opinion that even if the Barakars had not been pierced in the borings, they would be met with at comparatively shallow depth and that further borings may be made in the area.

Only one further borehole seems to have been sunk here by the same Syndicate in 1908, between Buchipalem and Atchipalem (the latter is about a mile south of Vadalagunta—17° 5′:81° 31′) to a depth of 793 feet. The strata passed through resembled Barakar sandstones and shales showing streaks of coal and carbonaceous material but no actual seam of coal was cut through.

The position is therefore that, though a number of drill holes have been sunk in restricted areas of Barakar and Kamthi rocks to the east as well as to the west of Zangareddigudem, they have not so far revealed the existence of any workable coal seams. The Kamthis cover a large area in this region and they apparently conceal the coal-bearing Barakars beneath them. The Kamthis are, however, not very thick and will not be an obstacle to borehole investigation of the strata beneath them. Since the finding of workable coal seams is a matter of great importance to the Province of Madras, it would be

worth carrying out a systematic investigation by boreholes say, reaching down to about 2000 feet—over the unexplored area so as to settle once for all the question of the occurrence of coal therein.

CHINGLEPUT DISTRICT

In 1891, Father Dominic put down a boring for artesian water for his monastery at Place's gardens, Kilacheri, about 6 miles from Kadambattur railway station. The surface rocks here are of Upper Gondwana (Sriperumbudur) age. In the annual report of the Geological Survey of India for that year (*Rec. Geol. Surv. Ind.*, XXV, p. 2, 1892) it is stated that the boring had reached a depth of 307 feet and had penetrated 25 feet thickness of carbonaceous clays. In Bruce Foote's opinion the associated strata were undoubtedly of Barakar age and indicated the possibility of the existence of coal.

Mr. D. E. W. Leighton who became interested in the question of finding coal here, organised a company, called the Arkonam Coal Co., but this does not seem to have done any work. Some years later Messrs. Best & Co. took up the matter and sank some boreholes, particulars of which are not available except that one borehole at Vengattur or Periyakuppam (some 16 miles from Arkonam) reached a depth of 991 feet. The strata passed through were examined by H. Walker of the Geological Survey of India who opined that they belonged entirely to the Upper Gondwanas in which coal was not known to occur.

Prospects

From the account given above, it will be gathered that no good deposits of coal have yet been discovered in this Province. The industrial backwardness of this Province can, in a large measure, be attributed to the lack of coal, for this fuel has to be imported either from Bengal, or Bihar or Hyderabad State. Before the Second World War the pit mouth value of coal was only around Rs. 5 per ton but the railway freight to points in the Madras Presidency averaged about Rs. 12. During and after the War both the price of coal and the railway freight have been increased so that a ton of good coal delivered in Madras and the interior towns costs between Rs. 25 and Rs. 30.

The finding of workable coal seams in this Province is therefore a matter of considerable import to the future of the industries, since a coalfield situated within the limits of the Province will effect considerable savings in freight and thus in the cost of coal consumed by the industries. It is for this reason that systematic search with the help of drills is advocated, though this would entail the expenditure of several lakhs of rupees by Government. Private companies have already done a considerable amount of work in this direction, and in view of the discouraging results obtained, they are not likely to come forward to incur further expenditure in drilling.

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CHAPTER XII

COLUMBITE-TANTALITE

Columbite is the columbate (niobate) of iron, while tantalite is the corresponding tantalate. Manganese sometimes, replaces iron to a certain extent. Pure columbite ($Fe\ Nb_2O_6$) should contain 82·7 per cent. niobium pentoxide (Nb_2O_5), and tantalite 86·1 per cent. tantalum pentoxide (Ta_2O_5), but the two form isomorphous mixtures so that, in nature, we find the mineral containing both niobium and tantalum in different proportions. The mineral is black, hard and heavy and is not visually easily distinguished from other black minerals unless chemically tested. The specific gravity varies from 5·3 for nearly pure columbite to 7·3 for nearly pure tantalite. The gradation of this property in the mixed mineral enables us to have a very fair idea of the proportion of the two from the measured specific gravity.

Tantalum is commercially much more important than columbium though both have been used in alloy steels. Tantalum possesses the property of being hard and resistant to acids especially after gas-hardening treatment. It is used in acid stills, pipes, condenser tubes, gaskets, etc. It can be used for making laboratory ware but should not be used with corrosive chemicals at a temperature above 400° C. It finds application in the rayon industry as spinnerets or perforated cups through which the cellulose solution is forced into the acid hardening solution.

It is used in electron emission devices (X-ray tubes, radio-valves, rectifiers, photoelectric cells, etc.) as it can absorb residual gases in addition to having other desirable properties and is in certain respects better than tungsten or molybdenum. It has also the property of transforming alternating into direct current, and is used as a cathode for the recovery of certain precious metals by electro-deposition from solutions.

For a short time before the discovery of the suitability of tungsten filaments for incandescent lamps, tantalum filament was used (especially between 1904 and 1909).

Tantalum carbide is very hard and has a very high melting point. The sintered carbide is used, with or without tungsten, niobium and other carbides, as an abrasive. They can be embedded in a metal of good workability like cobalt and used in high speed cutting tools of high efficiency, wear-resisting parts of machinery and in wire-drawing dies.

Niobium steel with high chromium has certain desirable properties, including high ductility. Nickel-chromium-niobium steel is resistant to corrosion.

Deposits

Columbite-tantalite is a comparatively rare mineral and occurs only in pegmatites. Though occasional crystals are found in many parts of the world there are very few areas capable of giving a small tonnage regularly. A few small occurrences are known in India, but none commercially important.

Nellore.—Dr. T. L. Walker noted the occurrence of this mineral in a pegmatite near Chaganam (14° 13′: 79° 41′). It had a specific gravity of 5·748. Though the pegmatite areas of Nellore were searched in 1942-43 for further traces of this mineral, only a few small pieces were got from the dumps of the L. N. and Palamani mines.

Madura.—Balfour states that ferro-tantalite was amongst the minerals collected by Rev. C. F. Muzzy in the Madura district. The district manual says that the mineral came from near Palni (10° 27′: 77° 31′).

Trichinopoly.—Mr. C. Middleton, once an active prospector in this Province, found a small quantity of columbite-tantalite in the Semmalai hills near Vaiyampatti railway station (10° 32′ 30″: 78° 18′ 30″) when opening up a mica pegmatite. A specimen sent by him to the Geological Survey was found to be nearer columbite than tantalite.

The pegmatites of this area were investigated by S. Narayanaswami in 1942. The pegmatite worked by Middleton is at the eastern end of the Semmalai E.N.E. of peak ·2229 feet and about 3½ miles W.N.W. of Vaiyampatti. About 400 feet from the foot, up the eastern flank of the hill, are hornblendic mica gneisses striking N.E.-S.W., and traversed by pegmatites, the largest vein being 150 feet long and 50 feet wide. Small pieces of columbite were noticed in the material dumped from the old pits. The pits were deepened but only a few sporadic pieces were got.

On the north-west flank of peak ·2026 feet, 1¼ mile south-east of Terku Aiyampalaiyam (10° 34′: 78° 10′) there are some old workings for mica. Almost due west of the above peak, there is a large pegmatite lens 400-450 feet long and 75 feet wide, with a central core of quartz which is 30-40 ft. wide. This pegmatite extends from the foot of the hill to about half way up the flank. The old pits in this pegmatite, mainly on its eastern and north-eastern side, were opened up and deepened. Several small pockets of columbite were discovered near the junction of the quartz core and the outer feldspathic portion. The total yield of all these pockets was barely 100 lbs. of columbite-tantilite and much more money was spent than the mineral was worth. The deposit is therefore of no economic value. The specific gravity of the mineral had a range of 5·23 to 5·48 (25 pieces used) and therefore towards the columbite end.

Salem and Coimbatore.—Small pockets of columbite-tantalite are found in the Srinivasa mica mine near Kurumbapatti (11° 35′ : 77° 52′), a few miles from Idappadi, Salem district, and in the mica mine at Vairamangalam (11° 27′ 30″ : 77° 37′) near Bhavani in the Coimbatore district. Pieces collected by Mr. N. K. N. Aiyengar in 1943-44 from these mines gave on analysis (Geological Survey of India laboratory):—

	Nb_2O_5	Ta_2O_5.
Kurumbapatti mine	66·47	7·6 per cent.
Vairamangalam	55·90	18·72 per cent.

Mr. Aiyengar learnt that during the War a consignment of 500-600 lbs. of the mineral gathered from the Srinivasa mine (probably in the course of a few years) was sent to Bombay for export to America. One exceptional pocket in this mine is said to have yielded about 200 lb. of the mineral.

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CHAPTER XIII

COPPER

Copper is one of the most useful metals, and because of its abundance in many parts of the world and the ease with which it is smelted, it has been employed by man for many centuries. It has been in use longer than iron and steel, particularly in the form of bronze, and it succeeded stone in the making of weapons for offence and defence.

Only rarely does copper occur in nature as the metal ('native copper'). The sulphides and carbonates are more common than other compounds and constitute ores. The more common ore minerals are the sulphides chalcopyrite, chalcocite, covellite and bornite; the oxides cuprite and tenorite; and the carbonates malachite and azurite. Copper deposits are usually associated with igneous rocks of an acid or intermediate character. Native copper occurs in the Lake Superior region of the U.S.A. in volcanic rocks. The sulphides form primary ores which are altered to oxides, carbonates and other compounds when subjected to alteration at and near the surface by atmospheric agencies.

The ore bodies are of different kinds. Solid lenses and veins of sulphides as well as sparse disseminations in igneous rocks yield the bulk of the world's copper at present. The latter type, known as 'porphyry copper ores' are worked on a large scale in western U.S.A. at present. Ores are also sometimes found in sedimentary formations as thin veins and disseminations as in the Kupferschiefer of Mansfeld, Germany.

Copper is first smelted to yield impure product—matte or blister copper. It is then refined by further smelting or by electrolysis, the latter yielding metal of high purity preferred for the electrical industry.

Copper is put to a variety of uses. In the electrical industry it is used for making parts of generators, motors, switches, etc., and as wire in power transmission, telephony and telegraphy. Various types of copper alloys are used in a variety of industries and the arts, including parts of machinery (bearings and valves), and vehicles of transport (ships, planes and locomotives) in the building trade and for domestic purposes. The metal and alloys are marketed in the form of wire,

rod, ingots, bars, sheets, tubes and castings. Some well known alloys are:—

Type	Composition	
	Cu	*Zn*
Brass	66	34
Brass	70	30
Muntz metal	60	40
Delta metal	56	42 (Rest mainly Fe)
Statuary brass	91	5·5 (Some Sn a, Pb)
	Cu	*Sn*
Speculum	66	34
Bell metal	80	20
Gun metal	90	10 (Some Zn, Pb, Sb)
Phosphor-bronze	82	13 (Some Zn, Pb, P)
	94	5
Manganin	85	10-12 Mn (4 per cent. Ni).
Monel metal	30	— (70 per cent. Ni).
Nickel-Silver	Cu-Zn-Ni alloy mainly	
Duralumin	4 95 per cent. Al (Some Si, Mg)	

Copper enters into the composition of numerous alloys as a minor constituent, *e.g.*, with aluminium, beryllium, magnesium, steel, etc.

The sulphate and arsenate of copper are used as preservatives of timber and for protection against insect pests. Copper sulphate is used in dyeing and the natural carbonates as paint pigments.

Distribution

Nellore.—There is a fairly extensive literature on the Nellore copper deposits and on the attempts made to work them since 1800. The deposits are said to have been exploited during the days of the

Vijayanagar kingdom—perhaps in the 13th and 14th Centuries but no account exists of the mining activities of those days. For recent accounts we are indebted mainly to Heyne, Newbold, Boswell and King.

Copper ore seems to have been re-discovered in Nellore in or about 1800, for in that year the district Collector transmitted to Government (East India Company) proposals by Captain Ashton for working copper deposits in the "western pollums" near Yerrapalle (14° 59′ 30″: 79° 36′ 30″) which, according to local traditions, had been worked some Centuries ago by the kings of Vijayanagar. The workings near Garimenapenta (14° 59′ 30″: 79° 33′), about 5 miles west of Yerrapalle, were discovered soon after. Dr. B. Heyne visited the area about this time and published an account in his 'Tracts' a few years later. A specimen collected by him was described as 'Mysorin' (a hydrated copper carbonate) by Thomson, but this was later shown by Mallet to be merely malachite with chalcocite and ferruginous impurities.

Samples of ore from Garimenapenta were reported to be high in copper, up to 70 per cent. Two veins were opened up by the Collector and followed for a distance of 30 feet. The veins were described as frequently varying in thickness. Consignments were sent to England and one of these, weighing a ton, yielded 9 Cwt. 1 quarter of copper on smelting (over 46 per cent. Cu). It is said that they were leased out to a contractor for 5 years.

Kerr examined the old workings and made an attempt to re-open them in 1831. During his work he discovered the existence of old slag heaps and also old galleries from the bottom of one of the pits which were cleaned up. James Prinsep who examined some samples and assayed three of them, found that they contained respectively 30·2, 39·5 and 69 per cent. of copper. Messrs. Hart and Simpson of Madras did a considerable amount of work on these deposits and are said to have spent about a lakh of rupees in exploration. Boswell has given, in the district manual, an extract from a note given by Mr. Simpson. J. Ouchterlony of Ootacamund made an attempt in 1842 to work the deposits, with the aid of a Cornish miner brought from England. His attempts have been described in a pamphlet printed for private circulation by his brother Col. Ouchterlony of the Madras Engineers.

At the time of Dr. King's visit in the 1870's, one Mr. Lavelle was trying to work the deposits. He opened up a lode three-quarters of a mile S.E. of Garimenapenta and followed it for 60 feet along the strike (W. by N.) and 22 feet down the dip. The ore was associated with quartz and the upper part of the vein had mica-schists and trap on the foot wall side. The vein was 2 feet 7 inches thick in general and ore yielded 28·75 per cent. copper. He also opened up a trench 55 feet long towards the east and raised 33,120 c.ft. of ore and gangue.

Lavelle opened up another lode outcropping in the stream course a mile to the east of the village and stated that this could be traced for about 2 miles. The lode where opened up was 3 feet thick and the ore recovered yielded 50 per cent. copper. A third lode was opened in the bed of a small tank close to and W. of N. of the village. Only a small quantity was dug up, as a heavy shower of rain flooded the workings. The ore from this assayed 54 per cent. copper.

For a long time afterwards nothing seems to have been done. Between 1923 and 1928 a lease of 5000 acres in this area was held jointly by Mr. J. A. Irani of Bombay and M. Waljee Laljee of Madras. As a result of dispute between them, 4750 acres of this passed under the control of Mr. Irani who floated a company called the Lakshmi Rangam Copper Mines Co. Ltd. in 1931. This company put down a few pits and some shallow drill holes but apparently failed to locate any important lode. It later engaged Messrs. Piepmeyer & Co., of Kassel, Germany, to carry out a geophysical survey. During a period of 3 months in 1933, the latter surveyed an area of 1700 acres by electrical methods and submitted report indicating promising zones and recommending that drilling should be done at a few specified spots to depths of 250 to 700 metres.

It appears that Messrs. Piemeyer & Co., were prepared to take over the deposits for working, but were prevented from proceeding with negotiations because of the embargo on export of capital from Germany. No drilling was done by the lesses to follow up the geophysical indications.

Mr. Waljee Laljee's property of 250 acres was transferred to Messrs. Sethia Valian Copper Co. of Ahmedabad who are reported to have done some prospecting since 1941.

Newbold has described 7 groups of deposits in the Garimenapenta area, as below:—

Kunchgarlaconda mines.—A little to the east of Samulrayacotta (Samalregada—14° 51′ 30″ : 79° 22′) a low spur is crossed by quartz in leptynitic gneiss, alternating with mica schist. Old exacavations, half chocked up, are found all along the ridge. Green carbonate and a vein 1 inch thick as also thin seams of iron ore are seen. The eastern base of the ridge is marked by a basaltic dyke 10 feet thick.

Salighirry mine.—The old mines are ½ mile S. W. of Garimenapenta. J. Ouchterlony had sunk some pits into the mica gneiss. The lode ran N.E. and was 3 to 4 inches thick. The debris showed grey sectile sulphuret of copper partly coated with green carbonate.

Nilagani.—This is half a mile S. of the village beyond the two tanks. The nearest mine is 50 paces by 5 paces in area and terminates below in a circular pool 10 paces in diameter. The ore occurs in mica and hornblende schists, mainly composed of green carbonate with fragments of dark sulphuret.

Bungheral Metta mine.—This lies in the area formed by the junction of the Pillaperu and Upputeru streams, 2 miles N.W. of the village. One of the excavations is several hundred sq. feet in area and 45 feet deep. Mr. Kerr is reported to have stated that there were galleries extending into the rocks from the bottom of this pit. Green carbonate is seen in thin layers in hornblende schists. A layer 2 inches thick runs down into the water at the bottom.

Cambaldinny mine (Kambhaldinne—15° 3′ : 79° 32′ 30″).—This is on the opposite side of the Upputeru. Carbonate veins up to 2 inches in thickness are seen in hornblende schists.

Yerrapilly mines (14° 59′ 30″ : 79° 36′ 30″).—Yerrapilly, 5 miles east of Garimenapenta, contains two mines, one north of the village and the other 1 mile to the S.E. Heyne stated that they showed 2 inch thick veins of carbonate and sulphuret.

Adimurtipuram (14°57′ : 79° 41′).—This is a little S.E. of Yerrapilly and shows garnetiferous mica gneisses and hornblende schists the latter containing streaks of copper ore. The last traces of copper to the eastward, found by Newbold are stated to be near Jungum (? Sangam) at the confluence of the Penner and Beyraperu, W. by N. of Nellore.

Newbold considered the Nilagani and Salighirry mines as the most promising.

When C. AE. Oldham (see *Mem. Geol. Surv. Ind., Vol. VIII, pp.* 270-271) visited the Garimenapenta mines in 1863, they were filled with water but there was evidence that large quantities of ore had been extracted from a zone traversing the hornblende schists. He traced the zone for a distance of 6 furlongs to 1 mile in a S.S.E. direction from the southernmost pit. The ore was found as thin laminae and disseminations in the schists. W. King who examined the area a few years later stated that the ore occurs in hornblende schists and garnetiferous gneisses which are associated with traps. There was no tolerably continuous lode or vein. The ore is copper glance in irregular masses with strings of malachite, occurring in massive earthy trap and in hornblende schists.

The copper country continues north into the Venkatagiri zamindari. At Gorganpully (? Gogulapalle—15° 15′ 30″ : 79° 22′ 30″) there were large workings 100 feet deep and several hundred feet long, worked before 1780.

Traces of copper carbonate were also found by King on a tank bund west of Kaligiri (14° 49′ 30″ : 79° 41′ 30″) in the material thrown out from the excavation of the tank.

Mr. K. K. Sen Gupta who examined the Garimenapenta area in 1927 estimated that the three groups of occurrences—Garimenapenta,

Kovaripalle and Nilgani—occupied an area of 10 sq. miles. At Garimenapenta there is a quarry 40 feet deep showing two zones of basic rocks with oxidised copper ores, malachite, chrysocolla and oxide. In the other two groups the ore is found in mica gneiss. In the large pit he estimated than 20 tons of ore would yield 300 lb. of copper though hand specimens of ore contained 30 per cent. or more of copper.

According to Dr. B. C. Roy who examined the area in 1943, the country rocks are garnetiferous mica gneisses usually extensively granitised, and altered basic eruptives, epidiorites and hornblende schists. The general strike of foliation is N.W.-S.E. varying to N.-S., the dips being generally westward or southwestward. The rocks are traversed by granite and pegmatite veins.

The ores seen at present in the old pits consist of stringers and lenticles in schists and in altered basic rocks, the maximum thickness seen being 8 or 9 inches. The ore consists of malachite, chrysocolla and chalcocite, the first sometimes forming a network of thin veinlets in chert rock. Mr. S. N. Sen, Assistant Geologist, Geological Survey of India, examined the area in 1946 and made some notes about the workings, which are described under a northern and a southern group. The southern group consists of several large pits including Nilagani and is situated at a distance of half to three-quarters of a mile S.E. and east of the village. The northern group, of 4 or 5 pits, is E. by N. of the village. Several of the pits have been dewatered and some ore won, especially from D and E_1 pits of the southern group by the present lessees. A stack of about 100 tons of ore taken from Extra-No. 2 pit (southern group) was still lying there, in the summer of 1946. Bulk samples of the ore recovered from these pits by the Sethia Valian and Lakshmi Rangam copper companies gave on assay, values between 1·3 per cent. and 5 per cent. copper.

All accounts go to show that the Garimenapenta area has been investigated only to a shallow depth, ranging from 20 to 60 feet and a few hundred tons of ore won during pitting operations by the numerous people who took an active interest in the area. All the surface indications have been tested, but no rich or continuous lodes have been traced so far.

The German Geophysicists have indicated certain favourable spots for drilling. It is thought that a check geophysical survey should first be undertaken, and if this confirms the previous results, drilling may be conducted at suitable spots.

Indications of copper ore are found elsewhere in this district near Pamur in the Kalahasti zamindari, Narasimhapuram (15° 0′ 30″: 79° 30′) in Udayagiri taluk and at Gogulapalle (15° 15′ 30″ : 79° 29′ 30″).

Guntur.—Old workings are found near the village of Gantlapalem or Agnigundala (16° 11′ : 79° 45′) at the northern end of the Vinukonda

dome. The workings are found in thick beds of granular quartzite containing films and veinlets or malachite and azurite. These do not seem to have received any attention in recent years. The locality was visited by Heyne and by Foote.

Kurnool.—Copper ore is said to have been worked formerly at Gani (15° 40′: 78° 20′) and copper used in the manufacture of bell-metal during the days of the Vijayanagar kingdom. Traces of copper ore have also been recorded at Gajjalakonda (15° 45′: 79° 24′) and at Kommemarri (15° 12′: 77° 53′).

At Gummankonda (15° 38′ 30″: 78° 18′) on the northern flanks of the Oondootla plateau between Kurnool and Nandyal, there are traces of old workings for copper in the quartz veins and traps traversing the Tadpatri shales. Foote states (*Mem. Geol. Surv. Ind.*, VIII, p. 268) that several of the quartz veins in this area are metalliferous. The longest of these, 3 miles long, traverses the Gumankonda valley and is mottled in appearance owing to its content of chlorite and talc. It has ben worked in several places. At the western end of Gumankonda there is an old pit more than 20 feet deep. The debris shows malachite and occasional azurite and copper pyrites. The original vein seems to have been worked out, leaving vertical walls of slate on either side.

In the deep bay in the hills east of Somayazulapalle (15° 35′: 78° 11′) there are two veins of white quartz running E.N.E.-W.S.W. about a quarter of a mile apart. The northern one is 4½ to 5 feet thick and shows grains and films of copper pyrites and malachite. No promising vein is seen.

Cuddapah.—In the rocks of the old lead mines at Jangamrazupalle (14° 46′: 78° 54′), a few miles north of the road from Nandialampet to Badvel, there are quartz veins showing traces of native copper and impressions of crystals of copper pyrites. The quartz veins traverse siliceous limestones in a N.N.E.-S.S.W. direction, and dip fairly steeply towards the W.N.W.

Anantapur.—A prospecting licence has recently been granted by the Government of Madras for copper ores at Mudigubba (14° 21′: 77° 59′). Nothing is known about the mode of occurrences or the prospects.

Bellary.—Newbold (1839) mentions the occurrence of copper ore on a low ridge below the southern scarp of the copper mountain 5 miles west of Bellary. No district lode was seen but only thin films of ore in ferruginous slaty rocks. Excavations made on the crest of the hill under Hyder Ali's orders were visible during the time of his visit. Foote states that he found no traces of ore on the copper mountain.

An occurrence of copper ore is found in the more northerly run of brecciated quartzite situated at a distance of a mile N.N.W. and north of the town of Harappanahalli (14° 47′ 30″: 76° 0′). On the eastern side of the saddle at the intersection of this ridge and the Harappanahalli—Nandi Bevur road, the quartzite shows some ore. A network of veinlets of malachite is seen for a length of several yards at a spot half a mile further E.S.E. Though poor this has been worked to some extent.

A reef of brecciated quartz occurs at the crest of Siddappan Konda about 2½ miles E. by N. of Hallalgundi (15° 29′ : 77° 4′). This extends 5 miles in an easterly direction from the hill to near the bank of the Haggari. Copper stains seen in this quartzite are not of commercial importance.

Coimbatore.—Extensive workings for copper (or gold) were seen on the northern slope of the ridge near Hadabanatta (11° 56′ 30″: 77° 19′). The old workings which rarely ever exceeded a depth of 20 feet, had been cleaned up by R. Morris. The quartz reef here is 2 to 8 feet thick, striking E.-W. and dipping to the south or S.S.E. It shows conspicuous malachite, copper pyrites, bornite, and iron pyrites in addition to quartz and chert. A sample collected from the reef by Hayden gave 3 per cent. coper and very little gold. Hayden has expressed the opinion that this reef would be worth opening up for its copper content.

Production and prospects

The only output recorded in recent years from Nellore is 14 tons of ore in 1926 and 1927 and 365 tons in 1932, the latter being valued at Rs. 6,900 at the pit mouth. The presence of numerous old workings testifies to the fact that several hundred tons of ore might have been removed in the past.

A perusal of the published literature indicates that there is a probability of meeting with copper ore in the Garimenapenta area in Nellore district and in the Hadabanatta mine in Coimbatore. With regard to the former, a geophysical survey may be conducted to check the results of the previous one done by the German firm especially as the pegs and other field indications left by the latter are said to have disappeared. If the check survey confirms the previous observations, then drilling may be undertaken.

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CHAPTER XIV

CORDIERITE

Iolite or cordierite ($Mg_3Al_4Si_5O_{18}$) is an orthorhombic mineral found in volcanic and metamorphic rocks. When transparent it is used as a gem stone. The usual colours are blue and violet, of various shades. Its hardness is 7 to 7·5 and specific gravity 2·6 to 2·66. Thin sections often show pleochroic haloes around radioactive inclusions. It shows a tendency to alter to a micaceous product called pinite.

Cordierite-bearing rocks have been described from the Madgul taluk in the Vizagapatam district by Walker and Collins. Cordierite is abundant in sillimanite-biotite-cordierite schists which are associated with spinel- and sapphirine- bearing rocks. The cordierite bearing rocks are considered as products of mixing and metamorphism of an ultrabasic suite of rocks and the khondalites of this region. The cordierite occurs in irregular grains and is not suitable for use as a gemstone.

The mineral was found in a garnetiferous gneiss occurring near Ganguvarpatti at the foot of the hills on the road to Kodaikanal. It was of blue to violet colour and transparent in thin pieces. It was apparently restricted to a lenticular band formerly worked for road metal.

Pale blue, transparent to slightly clouded, cordierite occurs in a few places in the Kadavur zamindari, Trichinopoly district. Some old pits about 2 miles west of Kiranur (10° 47′ : 78° 17′) are said to have been worked formerly for cordierite and pink corundum. The pits expose crystalline limestones, amphibolites and pegmatite and quartz intrusions. Similar material is seen near the temple one mile east of Kiranur, at a locality 1 furlong west of Kunnakavundanpatti and also half a mile west of the latter. Cordierite-bearing gneiss is seen in the dumps surrounding some old pits near Odaiyappatti (10° 37′ 30″ : 78° 15′) and near Ellammankovilpatti (10° 53′ : 78° 16′ 45″). In the last locality there is no crystalline limestone, the associated rocks being garnet-amphibolites and mica-schists.

In all the occurrences in Kadavur zamindari the mineral forms small lenses and streaky masses associated with vein quartz and granite-gneiss. The mineral is undoubtedly of metamorphic origin but whether the dolomitic limestone or para-schists gave rise to it has not been studied. It is white, light yellow, light blue or indigo blue in colour and transparent to translucent. Under the microscope it shows low relief low birefringence and occasional lamellar twinning and a high optic axial angle (negative). It seems to have been won for use as a precious stone, as it was mined together with

corundum and garnet. The local people say that some of the workings are more than a hundred years old and that some pits were put down between 1912 and 1919 by Messrs. Jinachand Dadhabhai Tata & Co.

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CHAPTER XV

CORUNDUM

General

Corundum is the natural oxide of aluminium (Al_2O_3) occurring in grains and well formed crystals, having a hardness of 9 on Moh's scale (next after diamond amongst natural minerals) and a specific gravity of 3·9 to 4·1. It may be colourless, grey, greenish or brownish, red, yellow, blue, etc. When transparent and flawless it is used as a precious stone, the ruby (red) and sapphire (blue) being the best known varieties.

Corundum occurs as a primary constituent of rocks having a high alumina content, such as syenite and syenite-pegmatites, ultra-basic rocks (anorthosites, pyroxenites) and metamorphosed aluminous sediments (in association with topaz, kyanite, sillimanite or dumortierite). It is also found in crystalline limestones, the alumina content having been transformed into this mineral. The desilication of granitic rocks, e.g., by limestones, is known to give rise to alkali rocks, the alumina set free in the process being crystallised out as corundum. **Emery** is an intimate mixture of corundum and magnetite or hematite. It is put to the same uses as corundum but no deposit has been found in India.

Uses

Due to its comparative scarcity corundum is not used as an ore of aluminium for which purpose bauxite is available. The chief use of corundum is as an abrasive in the form of bonded wheels and discs, as a coating on paper and cloth, and as powder. Superfine corundum powder (400—1,200 mesh), recovered from coarser corundum used in grinding operations, is employed in the optical industry for the finest polishing and as a special polishing medium for metals.

Distribution

Corundum deposits are known to occur mainly in the districts of Anantapur, Salem, Coimbatore and South Kanara districts.

The mineral from the detrital deposits which covered the outcrops of corundum bearing rocks have been collected probably for centuries and used by lapidaries for gem cutting and polishing. In a paper published in 1798 Greville has mentioned that corundum is found in the Trichinopoly district. Count de Bournon made a study of the corundum received from Salem, and incidentally gave the name 'indianite' to the feldspar species which is now known as 'anorthite'. Newbold has recorded a number of occurrences while Balfour has published an account of the abrasive materials,

including corundum, found and used in the Madras Presidency. Leschenault de la Tour has also described the lapidary's wheel used in Madras.

ANANTAPUR

The neighbourhood of Punighi in Hindupur is said to have yielded large quantities of corundum for export. Samples from this place were found to be associated with feldspar, mica, magnetite and spinel, similar to those from Mysore occurrences. As this region is on the Mysore border the deposits are probably a continuation of some of the Mysore occurrences. The mineral is also said to be available from other localities in the same taluk.

Sir Thomas Holland states that on enquiry the district revenue officers reported the presence of corundum in the following places, but the district has not been examined in detail geologically.

Anantapur taluk.—Atmakur (14° 38′ 30″ : 77° 22′), Danduvarapalle (14° 39′ 30″ : 77° 43′), Paramatiyelaru (14° 10′ : 77° 23′), Pasalur (14° 39′ : 77° 40′), Reddipalle (14° 43′ : 77° 42′), Siddarampuram (14° 40′ : 77° 20′), Thimmapuram (14° 42′ : 77° 23′).

Dharmavaram taluk.—Maddulcheruvu Sivapuram (14° 26′ : 77° 21′) Motaruchintarlapalle (14° 14′ : 77° 24′).

Hindupur taluk.—Punighi (Parigi 13° 54′ : 77° 28′).

Kalyandrug taluk.—Munirevu (14° 36′ : 77° 18′), Nutimadugu (14° 29′ : 77°20′), Obalapuram (14° 27′ : 77° 18′) Palavenkatapuram (14° 33′ : 77° 20′).

North Arcot.—B. Heyne states (p. 110) that he found corundum of the size of hen's eggs at Bombartipudi, 24 miles from Tirupati in North Arcot district. The associated rocks are described as hornblende schists. Holland thinks that the mineral may be hercynite. Bombartipudi is, however, not identifiable on modern maps.

SALEM

There are two groups of occurrences in this district one in the north in Dharmapuri taluk and the other in the south near the Cauvery valley.

In the *southern area* corundum has been won for probably two centuries or more. Count de Bournon described corundum from Salem in his classical papers published in 1798 and 1802. In his paper dealing with corundum and garnet, Newbold has mentioned several localities :—Namaul, Viralimodos, Low hillock near Cholasigamani, Caranal, Anpore, Mallapollaye (? Malayampalaiyam— 11° 12′ : 77° 50′) and other localities along the Cauvery valley up to Cocarambadi (? Kongarapatti—12° 2′ : 77° 43′). He also mentions

Topur Ghat (11° 57′ : 78° 3′) in Salem, and Chennimalai (11° 10′ : 77° 36′) and Gudejelhutty in Coimbatore. Several of the localities are stated to have yielded rubies, particularly Viralimodos, Cholasigamani and Mallapollaye. The corundum used to be sent to Palghat and western coast for export. It was sold at 15 to 30 measures (1 measure=about 57 oz. avoirdupois) per rupee, which would be roughly ½ to 1 cwt. per rupee.

The Sittampundi area was visited by Dr. H. Warth and Mr. C. S. Middlemiss in 1895 and 1897 respectively. At this time Messrs. Gordon Woodroofe & Co. of Madras were engaged in collecting or quarrying corundum here. Corundum-bearing plots were put to auction by Government and Mr. Govindjee Oodhavjee of Bombay took up several plots in 1899 and subsequent years. His son Mr. Madhavdas Govindjee continued winning until about 1914. The annual output in those years is estimated by local people at around 100 tons. A part of the area was worked in 1915-1917 by Mr. Alagappa Mudaliar and later by Mr. Arunachala Gownder. The present lessees are Messrs. Ajax Products Ltd., and Mr. Vishnu Nimbkar (and Mr. Tholasiram Chetty in the Mitta lands near by).

The southern belt forms a slightly elevated barren tract running in the form of a curve, convex to the south, from Pattalur (11° 16′ 30″ : 77° 48′ 30″) on the Cauvery in the west, through Molasi, Cholasiramani (11° 14′ : 77° 52′ 30″), Sittampundi (11° 15′ : 77° 54′), Pamandapalaiyam, Tottiyanattam, Chettiyampalaiyam (11° 15′ : 77° 59′), Karungalpatti, Kottakkalpalaiyam (11° 16′ : 78° 1′) Kallikkadu and Sayakkadupudur (11° 19′ : 78° 1′) to near mile 9½ on the Tiruchengodu—Namakkal road. Here the band bifurcates and one band proceeds to hillock ·641 one mile E.N.E. of Illuppuli. Another branch extends from Kallikkadu to hill ·751 east of Marappanpalaiyam, but these branches are rather obscure and poor in corundum. Corundum was also worked formerly at Chinna Taligai or Sandevipalaiyam (11° 16′ : 78° 5′) and this may lie on a connected band of corundum-bearing rock.

The corundum belt consists of anorthite-gneiss associated with pyroxene-garnet rock and amphibolite (partly chromite-bearing), in a country made up of biotite-gneisses. Corundum is found both in the anorthite-gneiss and in the pyroxene and amphibole rocks as grains, but the larger crystals, up to 3 inches in length, are largely confined to the anorthite-gneiss. The crystals are usually enclosed in a shell of calcite, and are barrel-shaped, with conspicuous horizontal striations. They are grey, bluish grey or brown in colour but some of the grains found in and near the contact of amphibole-schists are pink to red in colour. It is said that formerly rubies of marketable sizes used to be got here occasionally, and even now small grains of good red colour can be picked up.

The distribution of corundum in the anorthite gneiss is very irregular and the rock itself forms lens-like masses. In the anorthite gneiss are found also some zoisite, chondrodite, garnet and scapolite and small lumps of calcite. It is not known whether it is associated with any thin bands of crystalline limestone.

The detrital material covering the outcrop used to be worked for many years in the last century but during the last 30 or 40 years the mineral is got only from the anorthite gneiss which is blasted and broken up to separate the corundum. Though the outcrops have been opened up to a depth of 15 to 20 feet all along the belt, it is only the western end near Cholasiramani, Sittampundi and Pamanda-palaiyam which is now exploited. The quarries are in places 60 feet deep and the workings are not systematic or properly planned. The present output is of the order of 50 to 60 tons per year.

The anorthite gneiss and associated rocks may be of igneous origin, but metamorphosed later and subjected to hydrothermal alteration. It is thought that the corundum and the closely associated calcite may have been derived from the anorthite by the action of carbon-dioxide and water vapour, while the silica formed during the reaction may have been carried away in solution.

In the *northern area*, corundum is found in a tract 40 miles long by 1 to 5 miles wide, extending from Donnakuttahalli (12° 0′ : 77° 54′) in the south to Chintalagutta (12° 32′ 30″ : 78° 3′) in the north, the best portion being near Palakodu (12° 18′ 30″ : 78° 5′) and Papparap-patti (12° 13′ : 78° 4′).

The country rock is a biotite-gneiss frequently intermixed with charnockite. It is intruded into by syenite and syenite-pegmatite. The general foliation strike of the gneiss is N.N.E.-S.S.W. varying to N.-S. Corundum occurs rather sporadically in the syenite and pegmatite and occasionally in the gneiss and charnockite in their proximity, the corundum bearing portions having the shape of irregular lenses a few feet thick and up to 100 feet long. The mineral occurs as grains and crystals of varying sizes, up to 6 inches long. The crystals are hexagonal prisms often showing pyramidal faces and well developed parting planes. It is often associated with a hard black mineral occurring as irregular rounded clots and lumps which appears to be the spinel hercynite.

The more important localities in this belt which have yielded corundum are:—

	Lat. ° ′ ″		Long. ° ′ ″
Vishattipallam near Palakodu . .	12 18 30	:	78 5 0
Varattupallam near Papparappatti .	12 13 0	:	78 4 0
Malavur	12 13 30	:	78 1 30

	Lat.	Long.
Bellurpettai	12 12 0	78 4 0
Giddampatti	12 14 30	78 3 0
Tirumalaivadi	12 0 0	78 3 30
Erraguttumalai (·2321)	12 16 0	78 3 30
Gollapatti	12 18 0	78 3 30
Hanumantarayankovil	12 19 0	78 4 0
Jakkasamudram	12 23 30	78 3 30
Rayakottai	12 31 0	78 2 0
Nagadasampatti	12 8 0	77 57 30
Biliyanur	12 8 0	78 0 0
Harischandranur	12 7 0	77 59 0
Rangapuram	12 9 0	77 56 30
Mulakadu	12 10 30	78 14 0
Kuppankottan	12 18 30	78 3 30
Settihalli	12 21 0	78 3 0
Chintalagutta	12 32 30	78 3 0

This belt produced considerable quantities of detrital corundum from weathered outcrops for some decades prior to 1920, but the corundum-bearing rock has not been worked. The detrital material has now been exhausted. Mr. C. S. Middlemiss of the Geological Survey of India carried out prospecting operations in this area in 1897 to obtain an estimate of the cost of working the rock for its corundum content. 728 cwts. of corundum-bearing rock was blasted with gun powder and broken up by manual labour, yielding 2,845 lb. of corundum. The total cost including earthwork, blasting, breaking rock, sheds for workmen and sundry items (but excluding supervision) was Rs. 385-2. The cost of corundum worked out at 2·2 annas per lb. (around Rs. 300 per long ton). With regular working and mechanical aids for crushing the rocks, the cost can be appreciably reduced, though the higher wages of labour at present will partly offset the savings.

The yield of corundum from the rock in the above operations was 3·5 per cent. This is higher than the figure got by Mr. N. K. N. Aiyengar who put down a few pits in this area and who estimated that the yield would be around 2 to 2½ per cent. on an average.

Owing to the irregular distribution of the corundum bearing rock in this belt and the sporadic occurrence of the mineral itself,

it has not been possible to make any estimate of the reserves, but it can be safely stated that several thousand tons of the mineral will be available within a depth of 40 or 50 feet attainable in ordinary open-cast quarrying.

Trichinopoly.—Small quantities of corundum are found in the crystalline limestone band just south and south-west of Kiranur (10° 47′: 78° 17′) in the Kadavur Zamindari. The local people say that some gem quality pink and red corundum (ruby) was won many years ago from the old pits here.

Coimbatore.—At Selangippalaiyam (11° 26′: 77° 35′) in the Bhavani taluk corundum is found in the soil as scattered crystals but the mother-rock is not exposed. The country rocks are mica-schists intruded by pegmatites. The same is the case also at Gopichettipalaiyam (11° 27′: 77° 27′) and Shigrispalaiyam (11° 28′: 77° 20′). It is likely that the corundum is associated with pegmatite (syenite) rock intrusive into the schists.

Another group of occurrences is that of Kangayam (11° 0′ : 77° 34′), Kandyankovil (11° 1′ : 77° 28′), Karatupalaiyam (11° 3′ : 77° 31′) and Padyur (11° 4′ : 77° 29′). Between Karatupalaiyam and E.S.E. to Sivamalai, and especially up to the Tiruppur—Kangayam road, corundum is found as a constituent of syenitic rock along the northern foot of a series of hillocks. In the Sivamalai the same rock is associated with elaeolite-syenite. The syenite used to be worked more or less regularly some years ago and the mineral sold at Rs. 40 per **podi** of 192 Madras measures in the 1890's, according to Mr. Middlemiss. The corundum forms crystals of good size, up to 3 or 4 inches long and is of greenish grey colour.

South Kanara.—Sir Thomas Holland has mentioned that corundum has been reported from several villages in the Uppinangadi taluk. Dr. P. K. Ghosh who visited the area in 1935 reports that detrital corundum is seen in the alluvium of the Netravati river near Uppinangadi (12° 50′ : 75° 15′), Panchera (12° 48′ : 75° 17′), Pillenki (12° 48′ : 75° 18′), Barla (12° 49′ : 75° 16′) and Kaniya (12° 49′ : 75° 18′). The country rocks are granite gneisses intruded by pegmatites. The detrital mineral has been collected in a small way for many years but the pegmatitic rock has not been worked.

Other occurrences.—Corundum has been recorded from the Papikonda hills in the Eastern Ghats above Rajahmundry and from some locality in the Guntur district (*Sel. Rec. Govt. Madras,* Vol. 39, p. 90, 1857). Specimens used to be exhibited in the Madras Museum.

Another unconfirmed occurrence is reported in a zamindari area near Anakapalle, Vizagapatam district. I was shown some crystals alleged to have come from here but was unable to get any information about the locality.

According to records of production available, it seems to have been irregular and spasmodic, and I am not quite satisfied about their accuracy. However they are given below :—

Year	Cwt.	Year	Cwt.
1910	1686	1930	30
1911	3491	1931-1934	*nil*
1912	2931	1935	57
1913	1951	1936	67
1914	689	1937	...
1915	37	1938	10
1916	38	1939	15
1917	26	1940	...
1918	25	1941	4
1919-1925	*nil*	1942	453
1926	17	1943	150
1927	52	1944	86
1928	21	1945	395
1929	34	1946	404

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CHAPTER XVI

DIAMONDS

For many centuries until the discovery of the South Africa and Brazilian diamond fields, India was the main source of the world's diamonds. Three tracts in India have produced diamonds, the Mahanadi and Koel valleys in Orissa, the Panna State in Central India and the Ceded districts in the Madras Presidency. Of these it is only in the Panna State that a regular industry still survives.

In the Ceded districts the main source has been a zone of conglomerate in the Kurnool System (Banganapalle conglomerate) found in the northern districts of what is now the Madras Province were districts. According to Mr. P. Venkayya the source in several localities near Guntakal, Dhone and Gooty was the epidote-bearing pegmatite traversing Archaean gneisses.

Golconda in Hyderabad was celebrated throughout the world as the most important diamond mart, for most of the diamonds found in the northern districts of what is now the Madras Province were sent there for cutting, polishing and marketing. Golconda was one time the capital of a Moghul Province and it was natural that it should figure as the centre to which the produce of the mines flowed.

Considerable publicity has been given to the diamond mines of this region in the papers by Henry Howard, Earl Marshall of England, in his account presented before the Royal Society of England in 1677 when some 38 localities are said to have been productive. J. B. Tavernier, Baron of Aubbonne in France, travelled through India and published an account of his travels in 1684 in which descriptions of diamond mines in the kingdom of Bijapur and Golconda are given. Dr. V. Ball of the Geological Survey of India translated Tavernier's work into English and published it in 1889 in London and also wrote a series of papers in which he has described the deposits and identified the places occurring in Tavernier's accounts as many of them had ceased to be mining centres in the 19th Century.

The world production of diamonds, practically all from Africa and largely derived from the 'diamond pipes', averaged nearly 12 million carats between 1939 and 1944 (1 carat=0·2 gram). About 80 per cent. of this by weight, was industrial diamonds with a value of 30-35 per cent. while the rest was of gem quality claiming 70 per cent. of the value. From being a purely luxury article for many centuries, it is now also of great industrial importance as an abrasive, as a medium for drilling rapidly through rocks and hard substances and as dies for drawing exceedingly fine wires used for industrial purposes. A series of important papers on diamond has been published in three symposia in the American Mineralogist 1942, 1943 and 1946.

Distribution

Anantapur.—In a roughly rhomb-shaped tract bounded on the west by Lattavaram and Guntakal and on the east by Gooty and Dhone (including parts of Anantapur, Bellary and Kurnool districts) diamonds were worked in the 16th and 17th centuries. The most famous locality here is Wajra Karur (15° 2′: 77° 23′) about 8 miles south of Guntakal junction on the M. & S. M. Railway. Mr. P. Venkayya who resided for many years at Gooty and has carried on prospecting for diamonds and acquired intimate knowledge of this area states that epidote-bearing pegmatites intrusive into hornblendic and epidotic granite-gneisses of this region used to be worked for their diamond content. He has in his possession a fragment of pegmatite containing a small crystal of diamond which is said to have been recently examined by Prof. Paul F. Kerr of Columbia University, New York. He states that in several places in this tract (enumerated below) there are abundant debris of pegmatite rock crushed by the miners and small platforms on which the debris was washed. It may be stated on the authority of Bruce Foote and Mr. Venkayya that there is not a trace of the diamond-bearing Kurnool conglomerate in this tract, though Foote opined that the Kurnool formation might originally have extended to beyond Wajra Karur (15° 1′: 77° 23′) and Guntakal (15° 9′: 77° 22′) from its present limit east of Gooty (15° 7′: 77° 38′).

The localities in this tract mentioned as producing diamonds by Mr. Venkayya (some of which are described also by Henry Howard) are given below :—

Lattavaram (14° 55′: 77° 16′), Gadde Hootoor (Pedda Hoturu—15° 0′: 77° 18′), Ganjikunta (15° 0′ 30″: 77° 23′) Wajra Karur (15° 1′: 77° 23′), Bodasanipalle (15° 1′: 77° 26′), Konganapalle (15° 11′: 77° 32′ 30″), Mulakalapenta (15° 12′: 77° 31′), Upparapalle (15° 13′: 77° 37′), Jonnagiri (15° 14′: 77° 34′), Gade Anantapuram near Jonnagiri, Pagadirayi (15° 16′: 77° 35′ 30″), Peravali (15° 17′: 77° 30′), Girigetla (15° 17′ 30″: 77° 33′), Tuggali (15° 18′: 77° 33′). More than one large and valuable stone has been found at Konganapalle within the last 12 years, and the Wajra Karur neighbourhood is even at present yielding occasional stones to diligent searchers after good showers of rain. Numerous large stones have been recovered in this area during mining operations carried out in the 17th century, as testified by Howard. Bruce Foote mentions the find of a stone valued at over £10,000 near Wajra Karur, in the possession of Mr. R. S. Orr (of Messrs. P. Orr & Sons, jewellers of Madras) in the year 1886, and that several other valuable stones had also been found during the previous decades from the Wajra Karur neighbourhood.

In view of Mr. Venkayya's findings, interest attaches to the statement by M. Chaper, who visited Wajra Karur in the 1880's and did

NEMARA PUBLIC

some prospecting, that he got a diamond (as well as ruby and sapphire) from a pegmatite in an unspecified locality a few miles east of E.S.E. of Wajra Karur. But Bruce Foote disbelieved the statement; and it is still a mystery how ruby and sapphire were found there unless the contractor or mistry, interested in the prolongation of the prospecting work, introduced them surreptitiously; for there is no other record of corundum gems having been found in this area at any time.

Interest was aroused in Wajra Karur about the year 1880 by the recognition of the presence of an occurrence of a basic rock in a circular area resembling a volcanic neck, about a mile and a half west of this place. From the superficial resemblance of this to the famous diamond pipes of Kimberley in East Africa, a company was founded by Messrs. P. Orr & Sons of Madras in partnership with others to work the pipe. Mr. Copley, an experienced diamond miner from Kimberley, was in charge of operations. Though a large tonnage of the pipe rock was crushed and carefully washed in a well designed washing plant, not a trace of diamond was got.

As described by Foote and P. Lake the volcanic neck occupies an area of a few acres and forms a slight depression because of its comparative softness. The rock is an altered dolerite (epidiorite) and has no resemblance to the Kimberley pipe rock which consists of a serpentinous groundmass with fragments of peridotite, granite and others, and is really an explosion-breccia, the bulk composition being ultra-basic.

Bellary.—About 3 miles south of Huvin Hadagalli (15° 1′ 30″: 75° 57′) Foote noticed numerous small pits and washing platforms in a layer of conglomerate of Dharwarian age. They are probably the relics of mining for diamond on the mistaken supposition that these conglomerates were also of the same age as the Banganapalle conglomerate. There is no record of this place having produced any diamond.

Cuddapah.—The diamond workings of Chennur (14° 34′: 78° 29′) have been described in the Cuddapah district manual by Gribble. A bed of gravel here has been worked at a depth of 6 or 7 feet from the surface and diamonds obtained. King states that there is a tradition that two diamonds, valued at £3000 and £5000 respectively had come from here.

Near Kanuparti or Kondapetta (14° 33′ 30″: 78° 50′), on the left bank of the Penner river opposite Chennur there are extension workings covering an area of over one sq. mile. The workings are in a bed of gravel at a depth of a few feet below the prevalent black soil, the gravel being largely of chert, jasper and quartz pebbles. It is said to have been a fairly rich field but re-working in the 1830's did not seem to have been profitable. The area has been described also by Heyne and Newbold.

Olavampalli or Woblapalli, near Kanuparti has also yielded valuable stones from similar workings in gravel beds, according to Heyne and Newbold. A diamond sold for Rs. 1,450 was found here in 1839. The same authorities state that diamonds were obtained also at Lamdur and Pinchetgapadu to the west of Chennur, and at Gulagunta (14° 51': 78° 26'), Gurapur and Hussanapur (Dupaud) near Chennur.

East Godavari.—Diamonds are reported to be found occasionally in the bed of the Godavari river, near Bhadrachalam (17° 40': 80° 53'),

Guntur.—Extensive mining had been carried on at Kollur [(16° 43': 80° 2'), which is identified with Colour of Tavernier and Quolur of Howard] on the right bank of the Kistna, extending to the foot of the hills further in. Tavernier states that during his visit to this mine in 1645, some 60,000 people were engaged in mining operations. The pits were all shallow, not more than 14 feet deep and did not extend below the water level. The clayey gravel mined was dried, pounded with wooden hammers and winnowed, and carefully examined for diamonds. The 'Great Mogul' diamond presented to Emperor Shah Jehan by Mir Jumla in 1656, and which weighed originally 900 ratis (787½ carats) was said to have been got from here. During cutting its weight was reduced to 280 carats. Dr. Ball thought that this was the Kohinoor, now amongst the British crown jewels. The field is said to have become exhausted after a few years.

Howard has described the workings at Maddemurg, which has been identified by Ball as Mada gula (16° 30': 79° 35'), and which was the most productive locality of the district. The workings are said to have been closed prematurely on account of the unhealthiness of the locality. Other mines in the district were located at Mallavaram (16° 36': 79° 28'). Here the limestones at the base of a hill have been pierced through to get at the conglomerate below. There are also old workings in the Sarangapalli hill a short distance to the E.N.E., also on the right bank of the Kistna.

Kistna.—All the mines in this district are on the north of the Kistna river. The diamond bearing grits have been extensively worked in the Ustapalli hill (16° 42': 80° 10') and Kodavatakallu in the angle formed by the Munieru and the Kistna river. Heyne states that these mines are alleged to have produced several bullock loads of diamond when newly opened up. The same beds are found half a mile south of Ramanapeta near Jaggayapetta and near the abandoned village of Suravaram Kottapeta where they have been extensively worked. In the area between Nemalipuram and Cantranepalli, the diamond bearing grits show a slaty intercalation and the beds both above and below the slate zone have been pitted and searched.

At Partial (16° 39': 80° 25') and the neighbouring villages of Atkur, Barthenipadu, Mugalur and Munalur an earthy gravel was worked

at depths of 15 to 30 feet. Desultory working continued well into the 19th century.

Important workings exist in the lateritic gravel beds resting on the sandstones south of Golapilli (16° 43′:80° 55′). King states that both the Golapilli and Rajahmundry sandstones of the hills north of the Malavilli or Muleli in the Golapilli area were searched for diamonds. They were first discovered about 1670 and worked for several years, producing good stones at depths of 12 to 36 feet according to different writers who had seen the workings.

Kurnool.—Numerous places in this district, mentioned below, have produced diamonds in the past, mainly from a bed of conglomerate in the Banganapalle formation. Gopalakristnamah Chetty has given a good account of the mines in the Kurnool district manual, and other accounts will be found in the papers by Heyne, Voysey, Newbold and King given in the list of references.

King has described the occurrences near Banganapalle (15° 19′: 78° 14′) in his Memoir on the Cuddapah and Kurnool formations. The conglomerate forms the basal part of the lowest sandstone member of the Kurnool system which has been named after Banganapalle. This sandstone formation is exposed in a large area west of the town, forming the lower slopes of the hills and disappearing under the Narji limestone which caps the hills. The lower slopes of the hills have been pitted at numerous places to get at the conglomerate layer below, which is a mixture of clayey matter, grit and pebbles of chert, quartz and jasper. The conglomerate is easily broken after soaking in water for a couple of days and subsequent drying. The upper slopes of the hill have not been worked.

The formation extends for some 15 or 16 miles to the W. by S. of Banganapalle, to Madavaram and to the ruins of Munimadugu (15° 16′:77° 59′) where old pits are seen. Southward of Munimadugu to beyond the Penner, the formation can be seen but has not been worked. The Munimadugu area has not been exploited since about 1813.

East of Baswapur or Basavapuram (15° 24′ 30″:78° 38′) on the eastern side of the Kundair valley, there is an area of about 2 sq. miles at the base of the Nallamalais which has been searched for diamonds. The workings are partly in the conglomerate and partly in alluvium. Though similar formations are found southward of Basavapuram near Mahadevapuram and Rudravaram or Roodrar (15° 15′:78° 37′) and 1 mile further to the south, no workings have been noticed.

Small but excellent stones have been mined near Ramallakota (15° 34′ : 78° 0′—Raolconda or Ramulconeta of older papers) which

was formerly a taluk headquarters and of considerable importance. The mother rock was in the form of earthly veins traversing quartzitic sandstones at the edge and northern base of the hills (Ganighattu) E.S.E. of the village. In later years only the debris from older workings used to be washed.

Other localities mentioned are Bannur and Gudipaud (15° 44′: 78° 15′), Boyanapalle (15° 32′:78° 8′), Devanuru (15° 44′:78° 15′ 30″), Gattimanikonda (Gurumankonda—15° 32′:78° 11′), Coomroli or Komarolu (15° 33′ 30″:78° 10′), Deomuru (? Devamada—15° 49′ 30″: 78° 7′), Dhone (15° 23′ 30″:77° 53′), Gazulapalle near Baswapur, Kannamadakalu (15° 42′:78° 12′), Lanjapolur (15° 45′ 30″:78° 1′), Muravakonda (16° 1′:78° 16′), ? Voravakallu (15° 41′:78° 11′), Panchalingala (15° 52′:78° 2′), Poluru (15° 32′:78° 26′), Pyapalli (15° 14′:77° 45′), Satanikota (15° 55′:78° 12′ 30″), Tandrapadu (15° 51′:78° 4′), Timmapuram (15° 32′:78° 3′) and Yambayi (15° 33′ 30″:78° 7′).

Mr. A Ghose made some tests between 1910 and 1912 on a conglomerate at Virayapalle (15° 33′:78° 5′), which had a thickness varying from 3 inches to 2 feet. This gave an average yield of 0·4 carat per 16 cubic feet of rock, the diamonds being small crystals of fine quality.

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CHAPTER XVII

FELDSPAR

The feldspars are a group of aluminosilicates containing chiefly potash, soda or lime and occasionally other elements. The most important species and their composition are:—

—	SiO_2	Al_2O_3	CaO	K_2O	Na_2O
Orthoclase and microcline K Al Si_3O_8	64·7	18·4	—	16·9	—
Albite Na Al Si_3O_8	68.7	19·5	—	—	11·8
Anorthite Ca $Al_2Si_2O_8$	43·2	36·7	20·1	—	—

It is only rarely that any feldspar in nature approaches one of the above pure species. In general potash feldspars contain a little sodium. The soda feldspar is almost always mixed with a varying proportion of the lime feldspar and in fact there is a perfect gradation of composition between the two. A fine intergrowth of orthoclase with albite is called perthite, which is fairly common. Feldspar may also contain inclusions of quartz and other minerals.

The feldspars are generally white or pink. The green variety of microcline is called amazonstone. Albite having an iridescent sheen is known as moonstone, which is used as a gemstone. Labradorite, a variety intermediate in composition between albite and anorthite, sometimes shows beautiful green and blue reflections. All the species have a pearly lustre. Their specific gravity varies between 2·56 and 2·76, depending on composition, and their hardness is near 6 on Moh's scale.

Feldspars alter to kaolin and commercial deposits of kaolin are associated with and derived from highly feldspathic rocks. Cornwall stone, used in the ceramic industry, especially for making glazes, is a partly altered granitic or pegmatitic rock, containing a mixture of feldspar, quartz and kaolin, with often a little fluorspar.

The chief source of commercial feldspar is pegmatite which is a coarsely crystallised igneous rock containing quartz and feldspar with comparatively minor amounts of mica, tourmaline, beryl or other minerals. Pegmatites are extremely irregular in shape and size and are derived from and associated with granites.

Uses

Feldspar is crushed and ground dry and screened and the fine powder is generally air-separated for use for special purposes. The ceramic industry sometimes requires a granular product within

definite size limits, obtained by screening and air separation from material crushed to about 20-mesh size. Wet grinding in pebble mills and classifiers for recovery of graded products is also used. Electro-magnetic separation is used for getting rid of iron oxides, biotite, tourmaline, hornblende, etc.

The chief uses of feldspar are in the ceramic and glass industries where it is the source of the alumina and alkali required. In porcelain it forms 15 to 30 per cent. of the batch. A variable proportion is used in the manufacture of floor and wall tiles and in white ware and sanitary ware. Enamels for use on iron and steel need 25-30 per cent. feldspar in the batch mixture which includes also fluorspar, borax, soda-ash, etc. Some feldspar, to the extent of up to 15 per cent., is also used in glass compositions for ordinary purposes—*e.g.*, sheet glass, bottle glass and glass containers. In all cases it is necessary to know the chemical composition of the feldspar used so as to be able to control the composition and fusion characteristics of the final product.

Deposits

Granite and pegmatites are widely distributed in this Province and are found almost in every district except along the Coastal fringe and the area occupied by the Cuddapah basin. The possible resources may be declared to be inexhaustible though at present very little is known in detail about the deposits. A few recently gathered data are presented below:—

Bellary.—Pegmatites are widely distributed in this district, especially in the Bellary and Hospet divisions.

Chittoor-Arcot.—Granites and pegmatites cover extensive tracts in the Tiruttani, Chittoor, Katpadi, Jalarpet, Arcot, Tiruvannamalai and Gingee areas.

Trichinopoly.—Coarse pegmatites are very common in the southern and south-western parts of the district. Potash feldspar has been worked in a small way near Manaparai on the S. I. Ry. and supplied to the ceramic factory in Travancore.

Madura.—Most parts of this district contain pegmatitic rocks. Coarse pegmatites have been noticed in the Anamalai, Dindigul, Periyakulam, Tiruparankundram and Aruppukkottai areas.

Salem.—Extensive areas containing coarse pegmatites occur around Sankaridrug, Idappadi, Tiruchengodu and Paramati areas. The best area to exploit is the Suriyamalai and neighbourhood near Idappadi and Sankaridrug which is very largely made up of pegmatites.

A sample from the railway cutting a little to the east of Sankari-drug had a composition very near that of pure orthoclase with a small amount of soda replacing potash.

Nellore.—The mica belt of this district is full of feldspar rich pegmatite. Much good feldspar can be got from the dumps of various mica mines, in which there are reserves running into many thousand tons. The monthly additions of coarse potash and soda feldspars to the dumps should be of the order of 2,000 tons or more.

There are 3 general varieties of feldspar here; the most common is a white perthite. Less common is pink orthoclase in which the perthitic streaks appear fairly prominently and not so closely spaced as in the white variety. This is common in the Shaw, Tellabodu, Palamani, Killy, Pallimitta and a few other mines. A beautiful green perthitic microcline is found in a few mines—L. N., Rajeswari, Rama Vilas, Sudarsana Rama, Kubera—the dumps of which may contain 5,000-6,000 tons of this variety.

Partly kaolinised feldspar is found in a few places—*e.g.,* Gangadevipalle, F-mine, Sri Ramanjaneya, Muniria Vilas, Saraswati and Venugopalakrishna. This can probably be used as a substitute for Cornwall stone.

ANALYSES OF FELDSPARS, NELLORE DISTRICT

—	Sp. Gr.	SiO_2	Al_2O_3	Total iron (Fe_2O_3)	MgO	CaO	Na_2O	K_2O	Ign. loss	Total
1	2·626	67·19	20.20	0·08	—	0·61	9·85	2·10	0·16	100·19
2	2·621	67·25	20·35	0·05	—	0·72	10·15	1·59	0·14	100·25
3	2·561	64·27	18·70	0·07	0·02	0·05	0·36	16·05	0·20	99·72
4	2·566	64·32	18·95	0·31	0·02	0·09	0·64	15·49	0·30	100·12
5	2·576	65·15	19·19	0·22	0·01	0·14	2·50	13·02	0·20	100·43
6	2·578	64·89	19·15	0·09	0·01	0·16	2·44	13·10	0·18	100·02
7	2·581	65·47	19·31	0·15	0·02	0·17	3·51	11·52	0·20	100·35
8	2·570	64·85	19·00	0·22	0·02	0·07	1·84	13·99	0·21	100·20
9	2·584	65·34	19·10	0·34	0·01	0·10	3·03	12·23	0·33	100·48
10	2·572	64·83	18·82	0·27	0·02	0·08	1·70	14·09	0·16	99·97
11	2·573	65·08	18·95	0·14	0·01	0·10	1·95	13·89	0·22	100·28
12	2·574	64·82	19·01	0·10	0·02	0·13	2·12	13·52	0·21	99·93
13	2·569	64·71	18·85	0·31	0·01	0·08	1·56	14·36	0·30	100·18
14	—	64·42	16·42	0·32	—	—	3·96	14·48	—	99·60
15	—	64·72	16·76	Tr,	—	—	2·96	16·76	—	101·20
16	—	64·00	18·03	0·67	—	—	3·30	13·99	—	99·99
17	—	64·72	16·78	1·84	—	—	2·43	14·09	—	99·86
18	—	64·92	17·24	n. d.	—	2·07	1·12	13·08	—	—
19	—	65.00	20·66	—	—	3·12	9·21	0·46	—	—
20	—	63·20	18·32	—	—	1·64	1·18	14·10	—	—
21	—	64·32	19·10	—	—	1·30	1·08	12·48	—	—
22	—	63·44	22·38	—	—	4·06	0·69	8·07	—	—
23	—	63·60	18·80	—	—	1·50	5·47	9·15	—	—
24	—	60·16	24·00	—	—	0·70	6·25	7·05	—	—

1.	Albite-oligoclase	Tellabodu mine.
2.	Albite-oligoclase	Shaw mine.
3.	White orthoclase	Tellabodu mine.
4.	Flesh-red microcline	Pallimitta mine.
5.	Green perthite	L. N. mine.
6.	Pearl white perthite	Tellabodu.
7.	Pale green perthite	L. N. mine.
8.	Green part of 7	L. N. mine.
9.	Flesh-red microcline perthite	Pallimitta mine.
10.	Green perthite	L. N. mine.
11.	Pale green perthite	L. N. mine.
12.	Microperthite	Pallimitta mine.
13.	Flesh-red microcline perthite	Pallimitta mine.
14.	——	L. N. mine.
15.	——	R. Dibba.
16.	——	Marupur.
17.	——	Varadaraja mine.
18.	Flesh-red perthite	Killy mine.
19.	White albite-oligoclase	Shaw mines.
20.	Greenish microcline perthite	Srinivasa mine, Chennur.
21.	Green perthite	L. N. mine.
22.	Orthoclase perthite	Jayalakshmi mine, Orupalle.
23.	Flesh-red perthite	Venkata Kanaka Durga.
24.	Greyish perthite?	Kalyanarama mine.

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So far as can be ascertained, there has only been a small production from the Trichinopoly district in recent years. The few ceramic factories now existing in the Province probably get their requirements from their neighbourhood where the feldspar may be picked up from the surface or dug up from small burrow holes. The Nellore mica mines can supply large quantities and can look after any likely demand from industries in the neighbouring districts.

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CHAPTER XVIII

FLUORSPAR

Fluorspar or fluorite is the fluoride of calcium (Ca F_2—51·1 per cent. Calcium and 48·9 per cent. fluorine). It occurs in crystalline and massive forms, opaque or transparent and of different colours, violet, green and yellow being fairly common. It occurs in well developed cubical crystals in rock cavities or as veins in limestones or other rocks. It has a hardness of 4 in Moh's scale and a specific gravity of 3·18.

Fluorite is a fairly common gangue mineral in many sulphide deposits and is often associated with quartz, and calcite, sphalerite and galena. It is found as an accessory mineral in granite and as a replacement product in sedimentary rocks of suitable texture and composition. Commercial deposits comprise both veins in fissures and beds in sedimentary rocks.

Uses

The most important outlet for fluorspar is the steel industry in which it is used as a flux to the open-hearth charge. It makes the slag fluid and helps to remove phosphorus and sulphur from the steel. The quantity used in basic open-hearth practice is about 7 to 8 lb. per ton of steel made. It is also used in foundries, in the manufacture of alloy steels, ferro-alloys, nickel, monel metal, etc., and in the smelting of gold, silver, copper, lead, antimony, etc.

Other uses are in the manufacture of synthetic cryolite for aluminium metallurgy; hydrofluoric acid; opalescent and coloured glasses and enamels; calcium carbide; for recovery of potash from feldspar and from portland cement flue dust; in the manufacture of inorganic and organic fluorine compounds including the refrigerating medium called *freon* or F-12 (dichlorodifluoromethane). Transparent fluorspar is a component of optical systems for the correction of colour and spherical aberration.

Deposits

No fluorspar deposits are known in this Province. But very small amounts of the mineral and fluorapatite are minor constituents of granitic rocks in Northern Nellore. The granite occurs in a belt running nearly N.-S. through Kanigiri, Podili and Darsi taluks. No veins of fluorite were found in this area which has been geologically mapped, but the writer has seen a piece of fluorspar said to have come from this area, though its exact locality was not available.

This granite belt is characterised by the prevalence of the disease called fluorosis which affects the teeth of the human and cattle population. The fluorine obviously comes through the water, in the form of a soluble fluoride, the quantity determined by officers of the King Institute, Guindy, being around 3 parts of fluorine per million parts of water. In some cases 6 parts per million have been recorded. As the fluorite bearing granite must extend to great depths, deep wells cannot give fluorine-free water in this area. The only way of preventing the disease seems to be through treatment of the water to get rid of the fluorine or fix it in a harmless compound.

It is not unlikely that this area may contain some veins of fluorite or patches of fluorite-rich granite which may be made use of.

CHAPTER XIX

GARNET

This mineral has the general composition $3\ R''O.\ R_2'''\ O_3 \cdot 3SiO_2$ in which R″ may be ferrous iron, manganese, calcium or magnesium, and R‴ may be aluminium, ferric iron or chromium. It crystallises in the cubic system commonly as dodecahedrons and trapezohedrons, both these forms being conspicuous in garnet from the Nellore mica belt. Garnet has a specific gravity of 3·2 to 4·3 and hardness of about 7 to 7·5 which enables it to be used as a common abrasive. It is found as a constituent of mica-schists, khondalites (quartz-sillimanite schists), amphibolites and crystalline limestones, but the first of these is the most important source. The common garnet is the iron-aluminium variety called almandite, having a red or purple colour. The others—the pink to red magnesian variety pyrope, the orange-coloured manganese variety spessartite, the yellow calcic variety hessonite and the green chrome garnet uvarovite, are comparatively less frequent.

Uses

Garnet is won from mica schists and from disintegrated garnetiferous rocks or sands and used for abrasive purposes, after crushing and grading. When found in flawless fragments or crystals of good colour it is used as a semi-precious stone.

Distribution

Vizagapatam.—The Eastern Ghats, especially north of the Kistna, are made up of charnockites and khondalites and streams draining them show garnet-rich sands. As the coastal regions have not been surveyed it is not known whether there are any garnet-rich sands amongst them, but such a likelihood is strong.

Kistna.—In the fields at the foot of the hills, about a mile south of Kondapalle (16° 37′:80° 36′) transparent grains of garnet and quartz used to be collected formerly (King. *Mem. Geol. Surv. Ind.,* XVIII, p. 264, 1880). Even now some good transparent material can be got from here, but it is quite unimportant.

Nellore.—Parts of the mica-belt of this district have schists containing abundant, and often well-formed crystals. A hillock near Saidapuram (14° 11′:79° 45′) yields excellent dodecahedra while the neighbourhood of the Sankara mine near Griddalur (14° 16′:79° 47′) shows trapezohedra. The weathered schists are easily worked and the garnet separated. I have seen some good transparent material said to have come from the neighbourhood of Utukur (14° 14′:79° 44′ 30″).

Salem.—Newbold (*Journ. Roy. As. Soc.,* VII, p. 225, 1842) has recorded the occurrence of green garnet in certain quartz veins traversing

amphibole schists near Sankaridrug (11° 29′: 77° 53′). Opaque red garnets are abundant in the amphibolites occurring in the Kanjamalai and in the corundum area of Sithampundi in the Tiruchengodu taluk.

About 3 furlongs N.E. of Sevitturangampatti (11° 5′ 30″: 78° 10′ 30″) are some trenches opened up by a Madras firm for transparent red garnet associated with pale green amphibole. Similar abandoned pits are found also 3 furlongs south of Toppur (11° 6′: 78° 4′) and east of the Namakkal—Mohanur road.

About 1 mile N.E. of Tiruchengodu (11° 23′: 77° 54′) and 2 furlongs south of Kailasapalaiyam there are two small ridges containing garnet rich rock which can be crushed and the garnet separated.

Lumps of garnet, up to 10 inches in size are found associated with calc-gneiss 2 furlongs east of Tippampatti (11° 1′: 77° 51′ 30″) and also half a mile north of Mangarangampalaiyam (11° 27′ 30″: 77° 47′ 30″). At the last mentioned place the garnet occurs in lumps and masses up to a foot across. A garnet-rich granulite found in the Sanyasimalai in the Shevaroys has been marketed as 'emery' some years ago. This garnet has a dark coating of decomposition products which aids in the belief that it is emery.

Nilgiris.—Benza (*Madras Journ. Lit. Sci.*, IV, p. 266, 1836) has recorded the occurrence of the orange-coloured hessonite variety on the crest of a hillock called Seven Cairns (? Konibetta—11° 29′: 76° 44′). Parts of the rock are said to be composed entirely of garnet and amphibole.

Trichinopoly.—Massive garnet is reported to occur in crystalline limestones near Kalpatti (*Mem. Geol. Surv. Ind.*, IV, p. 275). Garnet derived from garnetiferous charnockite is concentrated in streams near Karai and Uttattur, where the lowest Cretaceous beds are also rich in them.

Ramnad.—A few small deposits of garnet-rich sand occur along the Coast south of Kaliman Kundu (9° 15′: 78° 53′ 30″) and south of Ammankudi near Mandapam. Here they are associated with a certain amount of ilmenite.

Tinnevelly.—Gem quality garnet is found near Melmattur (9° 34′: 77° 52′). It has pink to red-brown colour. There are four groups of localities on the Coast, which contain garnet-rich sands, according to Dr. Jacob. The Ovari—Navaladi (8° 15′: 77° 50′) area is the most important of these. The deposit near Ovari has been practically exhausted, but that near Navaladi is being worked, the garnet-bearing sand here being up to 4 feet thick; and the reserves would amount to many hundred tons of garnet.

A little to the south of the Nambiyar, near Kuttankuli (8° 13′: 77° 47′) the deposit is 4 furlongs long and 100 yards wide, the garnet-bearing layer being about 3 feet thick.

Some comparatively thin layers of garnet sand are found in the area between the mouth of the Nambiyar and Navaladi.

Prospects

The Ovari—Navaladi area has been worked, somewhat intermittently, during the last 2 decades and the garnet concentrate sold at Bombay. This area is estimated to contain some 36,000 tons of garnet and the Kuttankuli area some 20,000 tons. The garnet is derived from the disintegration of garnetiferous gneisses and charnockites of the Tinnevelly district, the garnet being concentrated by streams and brought to the Coast where it is reworked by the waves of the seas, helped by wind.

Little is known about the possibilities of the Nellore mica belt but it is learnt that this area is supplying the requirements of the abrasive factory of Ajax Products Ltd. at Madras.

CHAPTER XX

GEMSTONES

Gemstones or precious stones are substances mostly of inorganic origin, used for personal adornment because of their rarity and beauty. Those which are comparatively common, and therefore cheap, are treated as semi-precious.

The chief properties of gemstones are:—

1. Good colour and transparency.
2. Hardness and resistance to abrasion in ordinary use.
3. Lustre and brilliance—this property depends on the refractive index.
4. Special qualities such as pleochroism, silky sheen, cat's-eye effect, etc.

The brilliance and sheen can be brought out by careful cutting and polishing, taking advantage of the properties of the minerals such as pleochroism and the crystallographic direction in which certain effects are prominent. Stones with high refractive index and dispersive power are cut as "brilliants", others are step-cut or with a rounded surface ('en cabochon').

For the proper identification of gemstones a knowledge of certain physical and optical characters is necessary—specific gravity, hardness, refractive index (or indices) birefringence and pleochroism.

Pearl and jet, respectively calcium carbonate and carbon, are substances of organic origin.

The chief occurrences of gemstones in the Province are given below:—

Agate and Chalcedony

The varieties of cryptocrystalline silica, known as chalcedony and its varieties jasper, carnelian, plasma, heliotrope and agate (the last being the banded variety) are found in small quantities in the Deccan traps on either side of the Godavari near Rajahmundry. The gravels in this river contain these, partly derived from higher up the river.

Apatite

Crystals of deep sea-green apatite are found in the manganese mines of Devada (18° 15′:83° 35′) according to Fermor (*Mem. Geol. Surv. India*, XXXVII, p. 206, 1073; 1909). Several hundredweights of these are said to have been collected in or about the year 1905. Pale green apatite is also found in the pegmatite of some of the mica mines near Saidapuram in the Nellore district.

Beryl

The mica mines near Saidapuram, Nellore district (especially Vasantakalyani, L. N., and Killy mines) produce some beryl which includes transparent pale green portions which can be cut and used as aquamarine gems.

In and before the year 1832, Mr. J. M. Heath worked the pegmatites near Pattalai or Padiyur (11° 3′ 30″ : 77° 30′) in the Coimbatore district for aquamarine. Gems were found in cavities in the feldspar rock (Newbold—Beryl mine of Paddioor—*Mad. Journ. Lit. Sci.*, XII, pp. 171-175, 1840). In the Coimbatore district manual, published in 1887, F. A. Nicholson states (p. 23) that these mines during 1819-20 yielded 2196 stones weighing 22 lbs. and valued at £1210.

Chrysoberyl

Platy crystals of chrysoberyl are found sparingly in the corundum-feldspar veins of the Sivamalai area near Kangayam in the Coimbatore district. The crystals are usually too full of flaws to be of use as gemstones.

Cordierite (Iolite)

Translucent to transparent, pale, blue, cordierite is found in quartz and pegmatite veins traversing crystalline limestones and mica-schists near Kiranur (10° 47′ : 78° 17′) and Odaiyappatti (10° 47′ 30″ : 78° 15′) in the Kadavur zamindari. The mineral was won at these places formerly.

Corundum

Though corundum occurs in a 40-mile long belt of country in the Dharmapuri taluk, Salem district, no stones of gem quality have been found here.

In the Sithampundi area transparent red corundum, *i.e.*, ruby, is occasionally found in the chromite-bearing amphibolite associated with the belt of anorthite-gneiss. Newbold states that good rubies used to be got formerly from near Cholasiramani (11° 15′ : 77° 56′) and Viralimodos in this area (*Journ. Roy. As. Soc.*, VII, p. 224, 1842).

Pink and red rubies occur in crystalline limestones near Kiranur (10° 47′ : 78° 17′) in the Kadavur zamindari, Trichinopoly district, where it was won many years ago, as testified by the presence of several abandoned pits.

Diamond

For Centuries diamonds have been won from parts of the Godavari, Kistna, Anantapur, Cuddapah and Kurnool districts. In most places the conglomerate of the Banganapalle beds have been worked. Near Wajra Karur in the Anantapur district, however, there are no conglomerates though an appreciable quantity of diamonds has been got from here.

The following places are reported to have produced diamonds:

Cuddapah district.—Chennur (14° 34′: 78° 50′), Kanuparti or Kondapeta (14° 33′ 30″: 78° 50′), Obalapalle near Kanuparti, Hussanapur and Gulagunta (14° 51′: 78° 24′).

Guntur district.—Kollur (16° 43′: 80° 3′), Madugula (16° 30′: 79° 38′), Malavaram or Damarapad (16° 36′: 79° 29′) and Pulichinta near Kollur.

Godavari district.—At Bhadrachalam in the Godavari river.

Kistna district.—Golapilli (16° 43′: 80° 56′), and Malavilli nearby. Partial (16° 39′: 80° 26′) and a few other neighbouring localities, Ustapalli (16° 42′: 80° 11′).

Kurnool district.—Banganapalle (15° 19′: 78° 15′), Baswapur (15° 24′ 30″: 78° 39′), Devamuru (15° 49′ 30″: 78° 9′), Dhoni (15° 23′ 30″: 77° 54′), Gudipaud (15° 44′: 78° 16′), Munimadugu (15° 16′: 78° 0′), Oruvakal (15° 41′: 78° 14′), Ramallakota (15° 34′: 78° 1′), Timapuram (15° 32′: 78° 5′) and several other places.

There were many active workings during the earlier part of the nineteenth Century but the mining industry has completely died out later. Occasional surface finds are reported even at the present day, these being stray stones washed off from the disintegrated debris of former workings.

More details of the occurrences are given in the chapter dealing with diamonds.

Feldspar

Orthoclase and microcline are widely distributed in the Province and small quantities of suitable material, colourless, pale grey and pink, should be available if carefully looked for.

The green microcline called 'amazonstone' is found in some mines in the Nellore mica belt (*e.g.*, L. N., Kubera and a few others). It has so far not been utilised as a gemstone in this Province.

Garnet

Though Dr. W. King states that Kondapalle (16° 37′: 80° 36′) near Bezwada in the Kistna district is famous as yielding good quality

garnet, very little suitable material is to be found thereabouts at the present day. The mineral was probably derived from the khondalites.

Transparent garnet of purplish or violetish colour is found in the mica schists near Utukur (14° 14′: 79° 44′ 30°) and one or two other places in the mica belt of the Nellore district.

Near Ellamman Kovilpatti (10° 53′: 78° 17′) a few miles south of Kulittalai in the Trichinopoly district, gem quality garnet used to be recovered from the garnet-amphibolites and mica-schists. There are several old pits in this area as relics of former mining activity.

There are evidences of similar activity near Sevitturangampatti (11° 5′ 30″: 78° 10′ 30″) and near Toppur (11° 6′: 78° 6′) in the Salem district.

Good garnet is said to be available near Melamattur (9° 34′: 77° 52′) in the Tinnevelly district.

Fine red garnet fragments have been noted in some stream gravels near Subrahmanya in South Kanara near the Mysore border.

Kyanite

Blue coloured bladed kyanite was found by Middlemiss in the debris of pits, put down presumably for corundum near Kanjikovil (11° 22′ 30″: 77° 39′ 30″) in the Coimbatore district. Similar material occurs near Saidapuram (14° 10′ 30″: 79° 44′ 30″) and near Chundi (15° 6′: 79° 38′) in the Nellore district.

Quartz

Prisms and pebbles of rock crystal were once upon a time obtained in the bed of the Godavari river near Rajahmundry. Crystals are occasionally obtained in the mica mines of the Nellore district and from cavities in pegmatites and granite of other areas. Small crystals are said to be common in the neighbourhood of Karvetnagar in the Chittoor district and in the Satyavedu sandstones near Satyavedu in the Chingleput district. Pebbles of transparent quartz have been obtained for many years in small quantities from the Tertiary grits (Cuddalore sandstones) near Vallam in the Tanjore district and used locally for making trinkets, beads and spectacle lenses. Loose quartz crystals have been found in gravels at Sadanandapuram (18° 14′: 83° 34′) and rose-quartz in the manganese mines at Kodur (18° 16′ 30″: 83° 34′).

Opal

Wood opal and milky white opal are found replacing tree stems in the Cretaceous strata near Alundalippur and Malvay near Ariyalur in the Trichinopoly district. Opal has also been noticed in the Deccan

Traps of Pangadi near Rajahmundry; and replacing feldspars in the Kotakkarra (18° 22′ 30″:83° 31′) and Kodur (18° 16′ 30″:83° 34′) manganese mines in the Vizagapatam district.

Serpentine

Serpentine of pleasing colours—various shades of green and yellow-green—is found in association with the chrysotile asbestos near Pulivendla in the Cuddapah district. The material is rather brittle but can be made into trinkets and objects of art.

Tourmaline

Light green tourmaline, but not of gem quality, has been found near Kiranur in the Kadavur Zamindari, Trichinopoly district and in the Rajulacheruvu mica mine in the Nellore district.

Zircon

Crystals of zircon are found in the nepheline syenites of Sivamalai near Kangayam (11° 0′:77° 34′) in the Coimbatore district but they are only very rarely of gem quality.

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CHAPTER XXI

GOLD

Gold is one of the most sought-after metals because of its lustre, colour and resistance to atmospheric and chemical attack. It takes place with precious stones as something worth possessing, both as a means to personal adornment and as a commodity of lasting value to be exchanged easily for things necessary for one's existence. For a long time it has been considered as a medium of exchange. It is particularly valuable in disturbed conditions when it commands a ready standard of value.

Gold occurs both as the native element in the free state and as compounds, especially as selenides and tellurides. Native gold is found as nuggets and grains of various sizes. It is often associated with pyrite and other sulphides or as an alloy with silver, platinum, mercury, etc.

In early days, the main source of gold was the stream gravels in which it was found in the free state. Afterwards the free gold associated with sulphides and occurring as alloys with other metals were sought after. In recent times complex ores have become important, gold being a byproduct of the smelting operations designed to recover copper, nickel, cobalt, silver, etc., as the chief metal.

The two most common types of ores are the detrital gravels (placer deposits) and primary gold-quartz veins. The gravels are washed in water and the free gold therein concentrated by gravity. Gold-quartz veins have to be worked by regular mining methods, the material crushed to a suitable fineness and the gold recovered by blanketing, amalgamation or cyanidation.

Distribution

Gold is very widely but sparsely distributed in the area occupied by metamorphic and igneous rocks in this province, and many streams draining these rocks will yield small quantities of the metal from the sands and gravels. It is found in workable quantities in only a few restricted areas, particularly in the Wainad division of the Nilgiri district and adjoining parts of Malabar, in parts of the Coimbatore district, and in some of the bands of Dharwarian rocks occurring in the Anantapur and Chittoor districts.

BELLARY

Foote has noted the presence of numerous quartz veins on the southern and south-eastern flanks of the Jajkal hill (14° 51′:76° 1′) six miles E.N.E. of Harappanhalli. The gravels in the streams draining the area—*viz.*, the Konganahosur stream, a stream W by N of Chiggateru and one near Changalu on the western side of the hill—

used to be formerly washed for gold. Maclaren, however, states that exhaustive tests in the Konganahosur stream gave poor results.

ANANTAPUR

Mr. Wetherell of the Mysore Geological Department discovered a new band of Dharwarian schists in the Anantapur district in 1902. It is 32 miles long and runs into the Tumkur district of Mysore. Old workings in the quartz reefs were found in this belt, the country rocks being micaceous and chloritic schists.

In 1905, a company under the name of the Anantapur Goldfield Ltd. was formed to work areas near Ramagiri (14° 18′:77° 30′). It transferred a portion of its holdings (the Buruju block) to the North Anantapur Gold Mines Ltd. and another portion (the North and South Jubutil blocks) to the Nundydroog Mines of Mysore. The Jubutil Gold Mines of Anantapur Ltd. was formed to take over the properties of the Anantapur Goldfield Ltd.

This Company did much development work in the property which was situated 9 miles west of Nagasamudram on the M. & S. M. Railway, and the ore was treated in the plant of the North Anantapur Gold Mines. The capacity of the mill was 30 stamps which could treat 3,000 tons per month. Since the commencement of operations in 1909, the total gold produced was 136,739 oz. Some prospecting was carried on in an area 10 miles west of Pamidi railway station and near Palem (14° 55′:77° 28′) in the Gooty taluk where there were old mines. Leases were taken in the villages of Ramapuram and Venkatampalle and some gold extracted from the ores. The operations of this company, however, ceased in 1927. The North Anantapur Gold Mines Ltd. also had closed down mining operations in 1922—[*See Min. Mag.* (London) II, p. 10, January 1910]. The production of gold during 1910 to 1927 in Anantapur was as follows:

Year	Output	Value	Year	Output	Value
	oz.	£		oz.	Rs.
1910	2,332	10,120	1919	11,018	6,16,934
1911	5,284	20,835	1920	13,645	8,03,535
1912	7,269	28,499	1921	10,108	7,21,359
1913	11,019	43,194	1922	8,388	6,08,673
1914	19,873	82,959	1923	1,519	1,01,016
1915	23,870	101,324	1924	3,646	2,38,603
1916	22,371	94,789	1925	288	16,517
1917	20,529	87,066	1926	930	53,219
1918	17,831	67,219	1927	2,395	1,37,320

(Re. 1=1*sh.* 4*d.* until 1918).

COIMBATORE

Some auriferous veins occur in the Satyamangalam and Kollegal taluks of this district. The country rocks are charnockites intercalated with bands of biotite gneiss and basic intrusives. The outcrops have been formerly worked in a small way and abandoned when the miners encountered water in the workings. They are all largely filled up with debris so that a re-examination would require thorough cleaning up. Sir Henry Hayden examined the following deposits and the notes relating thereto are taken from his paper:

1. Bensibetta (11° 42′ 30″: 77° 18′) 12 miles S.E. of Bailur (11° 49′: 77° 15′).
2. Porsedyke mine near Porsegoundanpalayam (11° 53′: 77° 18′).
3. Hadabanatta (11° 56′ 30″: 77° 18′).
4. Kavudahalli (12° 3′ 30″: 77° 27′) 6 miles N.E. of Ramapuram (12° 0′: 77° 24′).

Bensibetta.—Several extensive workings are found to the east, north-east and south-east of Bensibetta, where a reef can be traced for 3 miles in a N.N.E. direction across this hill and on to a small hill one mile E.N.E. of the village Inbekombi. The southernmost workings are a little to the south of the Bensibetta Trignometric station.

The reef consists of stained quartz containing pyrite, limonite, hematite, chlorite, jasper, etc. The reef strikes N.-S. and dips westwards. A few hundred yards east of the main outcrop, which is seen to be dotted with numerous old workings, are some old shafts. Two of these, which had been cleaned up and prospected by one Mr. Morris, were examined by Hayden. The reef was 4 ft. wide. It was sampled and yielded some gold. The debris on this reef also gave visible gold when crushed and panned.

The northern shaft had been cleaned up to a depth of 50 feet along the lode, the thickness varying from 1·5 to 7 inches. Six samples taken from this reef showed a gold content varying erratically from 0·65 to 18·3 dwt. to the ton. Hayden calculated that this reef would have an average width of 5 inches and would yield 7 dwt. to the ton.

The second shaft exposed a thicker reef but it gave only traces of gold. There are extensive workings near the southern end of the reef (between Marur and Madikada) but the outcrops give only poor values, though the soil nearby always shows some gold. Extensive prospecting will be necessary to establish the workability of this lode.

Porsedyke.—This mine is 1½ miles N.E. of Porsegoundanpalayam and shows a large N.-S. reef on a small ridge. Three shafts have been sunk beside this ridge, without striking the reef. The reef and associated Dharwarian schists are surrounded by a large mass of pyroxenite (charnockite?). There are numerous old workings on the

reef which consists of stained quartz. Hayden recommends that the reef should be opened up and followed from the surface downwards.

Hadabanatta.—The lode seen near this village appears to be a continuation of the ridge of Porsedyke. Extensive old workings, to a depth of 20 or 25 ft., said to have been active in Hyder Ali's time, are seen on this lode. Besides quartz, the reef contains copper pyrites, bornite, malachite, iron pyrites, hematite, limonite, chalcedony, jasper, etc. Malachite is found in some abundance. The reef is 2 to 9 ft. thick, striking E.-W. and dipping at 33° to the south or E.S.E. Several samples taken from the reef in the cleaned-up old workings showed mostly traces of gold, only two samples giving 2 dwt. and 5 dwt. respectively. Near the surface the lode gives 3 per cent. copper. This lode is worth further exploration, especially as a copper proposition.

Kavudahalli.—Fairly extensive old workings are seen in this lode which is 3 miles north of Ramapuram. The reef strikes N.N.E.-S.S.W. and can be traced for 3 miles, over the whole of which there are old workings. The reef shows patches of pyrites and ferruginous material, and appears to be generally barren.

Some old workings are noticed 1½ miles N.N.W. of Hosur (12° 5′ 30″ : 77° 30′) about 7 miles north of Kavudahalli, but only a thin reef of quartz is seen which is apparently barren.

WAINAD-MALABAR

Over an extensive area, estimated at over 500 sq. miles, lying to the west of the Nilgiri mountains, gold has been won both from placers and reef deposits for centuries. The gold washing industry is extant even to-day and apparently gives a living to a fairly numerous community in this area. Nicolson's enquiry in 1831 showed that 500 to 600 people were engaged in gold washing at Kappil alone, and there were other places in the area where the industry was actively pursued.

Sheffield has given a list of streams in this area known to contain gold and also the results of an enquiry made by Lt. Nicolson in the year 1831. It was calculated that each gold-washer was able to win 2 to 6 grains of gold per day, the average being perhaps 2 grains.

In the year 1875, the Alpha Gold Co. was founded to prospect some of the reefs and in the same year Dr. King of the Geological Survey reported on the reefs and alluvial workings of Wainad. According to him, 15 of the reefs gave an average of 7 dwt. to the ton. In a later report (1878) Dr. King gave details of the prospecting work carried out by the Alpha Gold Co. and two other companies near Devala (11° 28′ : 76° 23′) and Pandalur (11° 29′ : 76° 21′). The yield from a total of 1,192 tons of quartz crushed was 271 oz. 9 dwt. 13 gr. giving an average

of 4·5 dwt. to the ton. In a paper published by Brough Smyth in 1880 at Madras, it is stated that the average for 88 samples dealt with by him was 1 oz. 8 dwt. 22 gr. to the ton (one sample as much as 204 oz. to the ton) and that the best average result of the Alpha Co. was 10 dwt. 12 gr. to the ton from 332 tons of quartz crushed by them. His report was on the whole favourable.

Though the average results taken for several workings in the area, were not particularly very attractive, the occasional finds of rich pockets and reefs seem to have been publicised in England, leading to the gold boom of 1880. Between 1879 and 1881, some 33 companies were floated in London with an aggregate capital of £4,050,000. Much expensive machinery was bought and installed, several Cornish miners brought over and money spent on buildings, roads and clubs. The reefs when opened up did not come up to expectations. Bad managements and generally poor results in mining conspired to bring about the suspension of activity by most of the companies by 1885. The Alpha mine worked until 1893 and the Phoenix just managed to pay and lived on for a few more years. Only 3 companies managed to survive till the end of the century.

John Darlington was engaged in 1883 to prospect six properties on behalf of the Indian Consolidated Gold Co. His report was not very favourable. He recommended extensive trial crushings to prove the value of the ores before large scale mining was undertaken. In the following year A. G. Charleton examined the same properties and came to much the same conclusion. He also examined the Phoenix deposits which gave only about 3 dwt. of gold to the ton on an average.

In the cold weather of 1899-1900, Dr. H. H. Hayden, Geologist, and Dr. F. H. Hatch, Gold Mining Specialist, attached to the Geological Survey of India examined several of the deposits and sampled them. 3500 ft. of the old drifts were cleaned up in the Alpha and Phoenix mines; the Skull, Cavern, Kuruman (Coorunber), Bear, Hamlin's, Monarch, Chulimalai, Hamsluck, Hamslade, Adelphi and Harewood mines, all near Devala; reefs on Dunbar, Balcarres, Richmond, Phoenix and Glenrock estates near Pandalur; Grange near Cherambadi; several reefs near Mappadi and Vayitri; all these were sampled, both for whole reefs and for the richer portions. The results were rather disappointing. The richer patches were small and irregular. The average reef yielded from *nil* to 4 dwt., with a mean of 2 dwt. In this connection it should be stated that the results of the work of several companies, between 1880 to 1883, tabulated by Leighton, showed that out of 3600 tons of reef quartz crushed only 482 oz. of gold was got, (*i.e.*, 9640 dwt.), giving an average of just under 2·7 dwt. to the ton. These results agree more or less with those got by Hayden and Hatch.

Geology.—The Wainad region is composed of garnetiferous biotite gneisses and hornblende gneisses having a dominant E.N.E.-W.S.W. or

N.E.-S.W. strike. They are cut up by granite and veins of quartz and pegmatite, some of the latter bearing workable deposits of muscovite. Intercalated with the gneisses are quartzites and magnetite-quartzites. Most of the quartz veins are lenticular but some continue for a distance of many yards. The reefs are generally parallel to each other, and somewhat oblique to the general strike, trending in a N.N.W.-S.S.E. direction. In the Alpha and Phoenix mines the reefs trend in a N.N.E.-S.S.W. direction. They dip generally towards the S.W. at 30°-40°, but higher dips are occasionally noticed. The reefs consist of brecciated and stained quartz containing pyrite, arsenopyrite, limonite, hematite, chlorite, talc, calcite and pyrolusite. The gold is often associated with pyrite but free gold is occasionaly seen. The reefs frequently show a selvage (or an external shell or coating) of brecciated quartz, limonite and talcose material, which is fairly rich in gold. Some reefs are rich in pyrite but this does not necessarily indicate the presence of much gold. The brecciated and stained reefs are usually richer in gold than those consisting of white quartz.

Below are given short notes on the various properties, taken from a recent report by Dr. H. Crookshank (published by the Government of Madras as Development Dept. G.O. 2224 of 19-9-1940).

Nadghani-Devala-Pandalur area.—The Nadghani (11° 28′:76° 25′) mine contains small reefs rich in pyrite but poor in gold. Numerous old pits here testify to much gold mining activity formerly.

The Alpha mine, 1 mile S.S.E. of Devala (11° 28′: 76° 23′) is a reef traceable for 1,100 ft. on the outcrop and 5 ft. thick on an average. It is recorded that 32,000 tons of quartz averaging 10 dwt. per ton were crushed in this mine. Most of this may have come from the northern part of the mine and from a rich run in the southern part. The rest of the mine apparently yields only an average of 2 dwt. per ton. As this mine contains the largest reef in Wainad and has been extensively worked in the past, it is likely to contain rich patches which would raise the average tenor of ore. Further investigation of this property is recommended.

The *Harewood mine,* 1½ miles N. by W. of Devala was sampled by Mr. K. K. Sen Gupta in recent years and according to him it contains at least 4500 tons of ore averaging 10 dwt. to the ton. As the reef extends below the lowest adit, it is likely to contain much more good ore. Moreover, there are several thousand tons of ore in the dumps which seem to be rich enough to pay re-working, according to Sen Gupta.

At the base of the *Chulimala* (11° 27′:76° 22′) there are several old cits and adits The reefs here are reported to be small and irregular. There are also several workings W.S.W. and north-east of Devala which are poor in gold.

The *Solomon mine,* situated just north of peak ·3983 N.W. of Devala, shows a reef 5 ft. or more thick. Old workings reveal this reef for a distance of some 260 ft. Though much ore has been removed from this mine, it may still contain perhaps 10,000 tons of ore, consisting of brecciated quartz poor in pyrite with probably 6 dwt. gold per ton.

The reefs just south of the main road between miles 33 and 34, known as the *Dunbar mines* have not been fully explored. Then contain much pyrite but samples gave rather poor results.

The Attikuna property, though showing several adits, is apparently not rich in gold. There was a stamping mill here originally but it has been dismantled and disposed of.

The Richmond property is situated on a hill half a mile east of Pandalur. A large mass of quartz has been opened up on the surface of the hill and worked extensively down to water level. The reef, which may continue still further down, is 7 ft. thick. The ore is pyritiferous but contains very little gold. This mine is said to have been investigated fairly thoroughly by John Taylor & Sons in 1902, but as they stopped further work, it is presumed that the results were unfavourable.

The *Rosedell mine,* situated between Pandalur and the Phoenix mine, shows a small steep-dipping pyritous reef. The upper adit is blocked and the lower exposes a reef 120 ft. long and 6-24 inches thick. Samples from the reef gave 12 dwt. to the ton. This property is therefore worth further investigation.

The Phoenix mine, situated on the southern flank of Ammanmudi betta (11° 29′:76° 20′) has been examined by Hayden and Hatch who concluded that it has reached lean ore. It was worked for 15 years, but the workings are now in a dangerous condition. But it may still contain some good ore at depth.

The *Glenrock mine,* on the scarp facing across the Glenrock valley, ¾ mile north of Ammanmudi betta, contains a reef 2½ ft. thick, pyritous and fairly rich in gold. The dumps of this mine are being worked occasionally by the local people. As there are numerous old adits here, the property should be worth further investigation.

The reefs seen on both sides of the road between mile 30 and Nellingalam (11° 32′:76° 22′) constitute the *Parcheri hill mines.* The material around the workings is still being occasionally flumed by the local people. A reef opened during the boom period is 5 ft. thick and 340 ft. long, and appears to be worth further investigation.

Oughterlony Valley.—Some old mines exist in this valley as well as to its south. Old mines are also located near Karembat on the Kalakapuzha, which is densely forested.

The *valley of the Punnapuzha* is rich in gold and washing has been carried on here for centuries. The area between Cheliapuzha and Nellikota Reserve Forest is a favourite section for gold washing, as also the bend in this stream S.E. of Nadghani. The gold content varies greatly but is naturally higher in the deeper gravels. Alluvial gold is also worked in the Cheliapuzha between Mambad (11° 15′: 76° 10′) and Nirpuzha Moku (11° 25′: 76° 15′). There are extensive old workings at Koppil, including some shafts and pits. The reef here is said to be 5 ft. thick and must be available for working below the water level. It is worth further investigation.

A dredger was working gravels a little above Mambad for a couple of years before 1914. The area is a little too rocky for such work.

Old adits are seen in the *Wentworth Tea Estate* area (11° 30′: 76° 17′) just south of Cherambadi (11° 31′: 76° 17′) and in the *Kottamalai* to the south of the former. Much stoping seems to have been done in the Wentworth property during the boom days.

The quartz reefs present in the *Ripon Estate* (11° 32′: 76° 11′), 4 miles east of Meppadi (11° 33′: 76° 8′), have not been fully explored. There are also numerous old workings in the Punnapuzha valley up to the top of *Vellarimala*.

Gold washing has been done in the gravels of *Cherupaya* north of Arikod and in the Beypur river near *Kishuparamba*. It is apparently still practised in the valley of the *Tariyot river* in the area north of Vayitri.

Old adits and pits are noticed in the Kuttakavu, Chundale and Thananjal Estates.

Prospects

The known gold bearing areas in Anantapur, Chittoor and Wainad, and especially the last, do not seem to have been thoroughly tested. Crookshank states that the numerous small but rich reefs near Devala and Pandalur in Wainad require further systematic investigation and are likely to be of importance.

As gold is generally associated with quartz veins in the Dharwarian schists, an accurate idea of the distribution of the latter is a necessary preliminary to the undertaking of detailed search for possible new deposits. This must await the results of systematic mapping of several districts occupied by Archaean formation.

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CHAPTER XXII

GRAPHITE

Graphite is a crystalline form of carbon found in igneous and metamorphic rocks either as disseminations or as veins. It may also occur in the form of graphitic schist mixed intimately with the other minerals in the schistose rock. The mineral is black and very soft and soils the fingers when handled. It is oily to the touch and has a specific gravity of 2·1 to 2·3. It has a good cleavage parallel to the basal plane of the hexagonal system in which it crystallises. The flakes are flexible and inelastic. It is infusible but a fairly good conductor of electricity. It resembles molybdenite (MoS_2) in colour, appearance and feel but the latter has a higher specific gravity (4·7) and gives a distinctly greenish tinge to its streak on a porcelain plate, (in contrast with the dead black of graphite) and can be chemically easily distinguished by tests for sulphur and molybdenum.

Graphite occurs as veins and pockets in granite and pegmatite; in crystalline limestone where it has probably been formed by the break-down of the carbonate molecule; in metamorphic rocks derived from carbonaceous sediments whose organic carbon content has been crystallised.

Graphite occurs either as crystalline flakes and lumps or as fine grained and powdery material. The former is referred to as 'flaky' and the latter as 'amorphous' graphite though the latter is in reality finely crystalline.

The mineral as mined is given a preliminary crushing and is hand picked. The finer material is ground in ball or rod mills. The product can be concentrated by froth-flotation. Electrostatic separation is also said to be effective.

Uses

Flake graphite is used for the manufacture of crucibles which are essential in the metallurgy of many metals. The graphite is mixed with a refractory binder like fire clay and shaped into crucibles.

Because of its extreme softness and flaky structure, it is an excellent lubricant for heavy machinery developing fairly high temperatures. It is used by itself or mixed with grease or oil.

It is employed in the manufacture of 'brushes' for dynamos and certain other electrical machinery and as electrodes for electric furnaces; also in stove polish and paint and as foundry facing. Fine grained 'amorphous' graphite is used in making ordinary 'lead pencils' and black crayons. For this purpose the graphite, free from grit, is mixed with black clay, kneaded and extruded through a machine in the shape of a wire which is cut to proper lengths and

baked. The hardness of the 'lead' is adjusted by the amount of clay added and by the temperature of baking.

The best grades of graphite for marketing contain over 90 per cent. carbon and it is possible to get 98 per cent. material from the Ceylon deposits. Second and third grades contain respectively 75-90 and 50-75 per cent. carbon.

Artificial graphite which can be used for certain purposes is made by heating anthracite or petroleum coke with quartz and sawdust at a temperature of 4000° C., when graphitic carbon is formed in a fine flaky condition. It is used in making dry cell batteries, polishes and pencils.

Distribution

Vizagapatam.—A deposit of good graphite is known at Tadepala village near Cherlopalem, a few miles from Narasapatam. A specimen from this area seen by me consisted of coarse flaky material. Other occurrences are reported near Salur (18° 31′:83° 16′) and Kasipuram (18° 13′: 83° 11′) and near Kesara in Kurupam Estate.

An occurrence is reported at Marupalle (18° 21′:83° 19′) in the Vizianagaram Estate where a narrow zone containing thin irregular veins is traced for a distance of 150 feet in and E.-W. direction and dips at 30° towards N. by E. It contains both flaky and fine grained varieties, but the quantity seems to be very limited. Other small occurrences have also been reported from this district, all of them probably small pockety deposits. One of these was at Vemuvilas, 16 miles from Vizagapatam on the Bimlipatam road.

East Godavari.—A good vein of flake graphite is said to have been found at Kothada in the Yellavaram taluk. Other occurrences are at Velegalapalle and Marinpalem in the same area. Graphite was worked for some time a few years ago near Sitapalle, Gollagudem and Ramanpalem in the Chodavaram division. It is reported to be worked now at Vootla and Vetakonda in Chodavaram and at Kalathanaur in Bhadrachalam. The associated rocks here are khondalites and granitic gneisses.

In the early years of this Century some deposits were worked in the Bhadrachalam division on the eastern flank of Pulikonda (17° 33′: 81° 26′), on the northern flank of Rachekonda (17° 32′:81° 25′) and on the southern flank of Sutrakonda nearby. According to Dr. P. K. Ghosh, the graphite occurs in khondalite traversed by pegmatite veins, as segregations and veins 1 to 2 feet thick. The veins run generally parallel to the planes of schistosity. In some cases they appear to have been 50 feet or more long and 4 or 5 feet wide. The deposits were worked for a few years before 1908, producing about 140 tons on the whole.

West Godavari.—A fairly good deposit occurs on one of the easterly spurs of the Samalkonda, about 1 mile north of Reddi Bodair (17° 19′: 81° 20′), some 15 miles north of Zangareddigudem, in the Polavaram division (formerly East Godavari). According to Mr. R. N. P. Arogyaswamy who visited the place, the deposit is up to 4 feet thick striking N.E.-S.W. in khondalites and gneisses traversed by pegmatites. The trench seen by him in 1942 was 250 feet long, 15 to 20 feet wide and up to 50 feet deep. Individual veins were up to 6 inches thick of pure flake graphite. It is reported to be worked by the Indian Plumbago Co. of Zangareddigudem. The deposit may hold a few hundred tons of graphite.

Stray pieces of graphite seen in the Mani *vagu* near Bedadanuru appear to come from small and insignificant pockets in the neighbouring gneissic rocks.

Kistna.—Bruce Foote reports (*Mem. Geol. Surv. Ind.,* XVI, p. 25, 1880) that the gneisses near Peddampur at the northern end of the ridge southeast of Amaravati contain a fair amount of spangles of graphite. No veins or good pockets are mentioned.

Trichinopoly.—An occurrence reported by the late Mr. P. N. Bose (private report to the Kadavur Zamindari) as molybdenite was found, on investigation, to be graphite. In a well 300 yards S.W. of Molaippatti (10° 4′ 30″: 78° 12′) and 1 mile southwest of Mettupatti, in the Kadavur Zamindari, are exposed a few parallel bands of graphitic micaceous schist, cut through by pegmatite veins. The bands are 2 inches to 12 inches thick and consist of decomposed gneiss containing fine grained graphite forming about 2-3 per cent. of the rock. The bands occur at a depth of 20 to 25 feet below the ground. The graphitic schist is not seen in the neighbouring wells and hence of very restricted extent. It is of little economic value.

Coimbatore.—Flaky graphite is found as a sparsely distributed component of the elaeolite syenite of the Sivamalai area near Kangayam. No useful deposit is known.

Tinnevelly.—A specimen of granite gneiss shown to the writer by the Chief Engineer for Electricity, is said to have come from near the Power house at Papanasam Falls. It showed nests of large flakes of graphite. It is apparently a stray occurrence as no other pocket was found in the vicinity.

A workable deposit occurs at Kurinjakulam (Pudukkulam—9° 14′: 77° 41′) in the Kuruvikulam Zamindari a few miles northeast of Sankaranayinarkovil. The graphite is a fairly rich constituent of the gneiss which is intercalated with granitic gneiss and crystalline limestone. The main graphitic band is exposed in the stream-bed and cart track near the village. It is about 10 feet thick, but appears much thicker because of folding. Pits were put down in this deposit

and the material got was crushed and concentrated. The average content was found to be 3·5 per cent. of the rock.

A few small exposures of similar graphitic gneiss are seen about a mile north of the village; the bands here are 5 to 20 feet thick.

Mr. S. Narayanaswami who examined these deposits in 1944 estimates that they contain about 660 tons of recoverable graphite within a depth of 20 feet. Of this, 560 tons are in the main deposit which is 1000 feet long and 8-10 feet thick on the average. The four other bands are much smaller, the largest being 100 feet long. The deposits are likely to be more extensive than assumed for the calculation of reserves. They can be easily worked on a small scale. Mr. V. S. Sambasiva Iyer who examined these deposits some 15 years ago and reported on them to the Zamindari, appears to have been misled by the thickness of the folded band to estimate a much larger tonnage.

A few other small deposits of a pockety nature have been found in this district, which is geologically similar to Ceylon and Travancore whose graphite deposits are well known. The deposits which came to the notice of the Geological Survey are in the Singampatti Zamindari on the northern flank of Gopurakkal and, on the northern slopes of Kottadi Mottai. The last is said to have produced a few tons of graphite two or three decades ago.

There has been no regular production of graphite in this Province. Intensive search in the khondalite areas of the Northern Circars and in the Tinnevelly district are likely to result in the discovery of a few deposits though no opinion can be hazarded whether any of the deposits would be of much importance.

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CHAPTER XXIII

GYPSUM

Gypsum is the hydrous sulphate of calcium ($CaSO_4 \cdot 2H_2O$) containing 32·5 per cent. CaO, 46·6 per cent. SO_3 and 20·9 per cent. of water. It is soft (hardness 2 on Moh's scale) and can be easily scratched by the finger nail. Its specific gravity is 2·32. It is generally white in colour but pink, brownish and yellowish colours may also be met with. It is appreciably soluble in water (about 2 parts in 1000) so that deposits are liable to solution and recrystallisation to some extent.

Very large and commercially important deposits of gypsum are associated with rock salt deposits and are thought to have been formed by the desiccation of bodies of sea-water partially cut off from the sea. Normal sea water contains about 38·5 grams of soluble salts per 1000 grams of water, composed of 29·7 grams common salt, 1·75 grams calcium sulphate, 2·48 grams magnesium sulphate, 3·32 grams magnesium chloride, the rest consisting of other sulphates, chlorides, bromides, etc.

According to A. W. Grabau (Principles of Stratigraphy, p. 349) calcium sulphate begins to deposit when the volume of sea-water is reduced by evaporation to 19 per cent. of the original (density 1·126) and continues until the volume is reduced to about 9·5 per cent. (density 1·214). At this stage, or slightly earlier, common salt commences deposition, and about 84·3 per cent. of the calcium sulphate content is thrown down, as gypsum. Gypsum continues to deposit until the solution reaches a density of 1·2627 by which time 78 per cent. of the common salt content is also deposited. (The above data relate to experiments conducted at 12·5° C.).

Posnjak states (*Amer. J. Sci.*, *238*, 559-568, 1940) that sea-water evaporating at 30° C. will deposit gypsum when the concentration of salts reaches 3·35 times the normal one and will continue until it becomes 4·8 times the normal. Beyond this point some anhydrite ($CaSO_4$) will be deposited for a while.

Gypsum is also found as crystalline plates in marine silts on the coast periodically inundated by sea-water. It may be formed as a result of replacement of limestone through the agency of sulphate-waters. Such replacement deposits are not uncommon.

Uses

The chief uses of gypsum are as the raw material for making plaster of Paris and Keene's cement and ammonium sulphate; as a filler and as a retarder in Portland cement, etc.

Gypsum plaster is made by heating the mineral at 160°-240° C. when part of the water content is expelled. The resulting material, when ground, is called plaster of Paris which is used in making casts and moulds and in the building trade. It is also used in Trichinopoly to make crayons (white as well as coloured) for writing on black board. If all the water in gypsum is driven off, it becomes dead-burnt and loses the property of setting.

Gypsum is heated to redness in kilns, then soaked in a solution of alum, again heated to redness and finally ground. This product is *Keene's cement*. *Parian cement* is made similarly but the material is steeped in a solution of borax instead of alum.

Gypsum has been used as a filler in the paint, paper and other industries to some extent and as a polishing medium for plate glass. Added to Portland cement to the extent of 3 to 5 per cent. of the weight, the setting time of the cement is retarded and can be controlled as required. The mineral is used on land as a soil conditioner, alone or in conjunction with fertilisers.

Anhydrite (which is of the same composition but without the water of crystallisation) has been used for several years as a source of sulphur in the manufacture of sulphuric acid. There is no reason why gypsum could not be similarly used.

Distributions

Trichinopoly.—The most important deposit in this Province is found in the Cretaceous rocks of the Trichinopoly district. The mineral occurs as veins traversing the clays and slits. Their thickness ranges from a fraction of an inch to 6 or 7 inches and they lie in all attitudes in the clays. The area in which gypsum is found is about 22 square miles, between Chittali (11° 15′ : 78° 58′ 30″) in the north and Tappay (10° 59′ : 78° 55′) and Periyakurukkai (11° 2′ : 78° 50′) in the south. The main area is in the western part of this belt but patches are seen also near Kunnam (11° 14′ : 79° 1′).

The results of some prospecting work carried out in this area show that the mineral forms 0·75 to 1·5 per cent. of the volume of the strata, the average being perhaps around 1 per cent. Gypsum is noticed in pits and sections to a depth of at least 30 feet and there is little doubt about its continuing to 50 feet depth. The quantity estimated to be present in this area is of the order of 15,300,000 tons within a depth of 50 feet from the surface. This estimate is based on the material actually recovered from prospecting and working pits.

The gypsum as recovered from the strata contains a little clay adhering to it, but most of it falls off on drying or washing in water. Sometimes some chalk and limonite are found attached to the mineral. The washed gypsum marketed from this area contains 80 to 90 per cent. $CaSO_4 \cdot 2H_2O$.

Tinnevelly.—Gypsum occurs in the form of crystalline scales mixed with and coating kankar (calcareous tufa or nodules) in the black cotton soil tract of the northern part (Kovilpatti and Ettaiyapuram) of this district. The mixed material is found at a depth of 5 to 10 feet from the surface, in a zone which is 1 or 2 feet thick. Similar occurrences are known in some other black soil areas, *e.g.*, in the Palladam taluk in Coimbatore. The powdered material is used in Tinnevelly for clarifying the water in the tanks. For this purpose a small quantity is powdered and calcined and thrown into the tank. The muddiness disappears in a few hours and the water becomes clear.

Nellore.—Along the northern border of the Pulicat Lake east of Sulurpet (13° 42′:80° 1′) is a large low lying area which becomes inundated during the monsoons. This area contains plates and crystals of gypsum often forming a thin layer in the silts within a depths of 3 or 4 feet. In an area of about 20 square miles which was examined by Dr. B. C. Roy he estimated that the quantity available was about 10,000 tons for every foot of depth, per square mile area. As the low-lying tract has an extent of over 100 square miles the mineral may be found over a large part of this.

Guntur.—Bruce Foote reported that the excavations in the marine silts of the Guntur Coast near Santaravur (15° 48′:80° 16′), for the Kommamur Canal (extension of the Buckingham Canal) showed crystalline plates of gypsum in fair abundance. A few trial excavations made in this area showed that the mineral is found at a depth of 5 to 8 feet and that its distribution is irregular.

Similar occurrences are also noted at Allur and other places near Kottapatnam (15° 26′ 30″:80° 8′ 30″). It is doubtful if these thin layers and sparsely distributed material at a depth of 5 feet or more from the surface will pay to work.

Chingleput.—Similar material occurs also in the estuarine silts near Ennore or Ennur (13° 13′:80° 20′) and other places north of Madras. The distribution is very sparse.

It may be mentioned here that the sea is an inexhaustible source of gypsum. The mineral is deposited to a large extent before the common salt. In the salt pans along the Coast the fine grained crystals of gypsum would be mixed up with the mud at the bottom of the impunded water and lost. It would be useful to conduct experiments in the salt producing areas to see if a good part of the gypsum could be recovered economically. The amount of gypsum in sea water is about 1/20 of that of the salt, but even this should form an appreciable quantity considering the fact that this Province produces annually a large tonnage of sea salt.

Production

Gypsum is produced chiefly in the Trichinopoly district though in recent years a small tonnage has come from the Sulurpet area of the Nellore district. The total output from this Province is given in the accompanying table. It is all used in the cement factories in Madras and Hyderabad.

Year	*Tons.*	*Year*	*Tons.*
1929	23	1938	9381
1930	42	1939	9812
1931	4	1940	18754
1932	75	1941	17138
1933	98	1942	22404
1934	55	1943	12736
1935	528	1944	16880
1936	1506	1945	27811
1937	1597	1946	15301

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CHAPTER XXIV

IRON

Iron is one of the most abundant constituents of the Earth's crust. This very abundance makes it necessary to search out high grade ores and utilise them for the extraction of the metal. There are literally hundreds of minerals of which iron is an important constituent, but only those mentioned below are of importance as forming large deposits which can be commercially utilised.

Magnetite (Fe_3O_4) also known as magnetic iron ore contains 72·4 per cent. iron. It is black and metallic looking, with a hardness of 5·5-6·5 and specific gravity of around 5·17. It is strongly attracted by a magnet.

Hematite (Fe_2O_3).—This is known as red iron ore or red oxide, containing 70 per cent. iron. It is dark grey or brown in masses, but the colour of the powder is characteristically cherry-red. Its hardness is 5·5-6·5 and spcific gravity 4·9 to 5·3.

Limonite ($2Fe_2O_3$ $3H_2O$) is a hydrated oxide containing 59·8 per cent. iron. The common brown ore is however a mixture of hydrated iron oxides in which the iron content is variable, but around 45 or 50 per cent.

Siderite ($Fe\ CO_3$) or spathic iron ore contains 48·2 per cent. iron. Its hardness is 4 and specific gravity 3·85.

Pyrite ($Fe\ S_2$) containing 46·6 per cent. iron occurs in large deposits but is only rarely used as a source of iron after the complete removal of sulphur. The sulphur content is used to manufacture sulphuric acid and the iron oxide residue may then be utilised as a source of iron.

The largest commercial deposits worked at present in various parts of the world are composed of hematite. Magnetite deposits are being exploited in Scandinavia while siderite deposits are worked in France and Luxembourg. Though siderite is comparatively poorer in iron than the other ores, its easy fusibility is a factor of great importance in its utilisation.

Steel-making in former times

Numerous papers have been published describing the processes used by the men engaged on iron and steel making in India in former times. It would appear that almost any type of ore was used, provided it was friable and easily collected. Thus hematite, magnetite and limonite served them equally well and were often used in a coarse powdery condition.

The usual type of furnace used in Salem had a circular cross-section of 2 ft. diameter, tapering towards the top. The height was about 4 ft. The furnaces in Malabar were rectangular in cross section (2½ ft. × 3½ ft.) and 10 ft. high. The Salem furnace took about 3 hours for a heat while the Malabar one took 50-60 hours, the weights of the blooms got in the process in the two districts being respectively 15-20 lbs. and 500-600 lbs. respectively.

In Trichinopoly, the wrought iron was carburised in clay crucibles which were usually 6 in. long and 3 in. across. The charge consisted of pieces of wrought iron together with charcoal which would amount to about 5 per cent. by weight of the iron. The mouths of the crucibles were closed with clay and they were arranged in a pile over the slightly arched bottom of the furnace. Charcoal was added from a hole at the top of the furnace and blast was supplied by bellows arranged around the neck of the ash-pit below the charge. The contents of the crucibles generally became molten during the process and each crucible yielded about 10 lb. of conical shaped ingot. This product was the famous *Wootz* steel. No *wootz* was produced in Salem during the nineties, but only decarburised steel which was made from carbon-rich iron.

Though much of the wrought iron and steel produced in indigenous furnaces by artisans was of excellent quality, all investigators agreed that the process in use, which followed rule of thumb methods, entailed an enormous wastage of time, heat, energy, ore and metal. Since no flux was used, a large percentage of the iron was lost in the slag. The furnaces were of poor construction and were wasteful in every way judged by modern standards.

Attempts at conducting a modern industry

In 1830, Josiah Marshall Heath, who had formerly been in the service of the East India Company, obtained exclusive rights to manufacture iron on a large scale in Madras. Works were erected at Porto Novo in or about 1833. A few years later, works were also built at Beypore in Malabar. The undertakings were not successful and by 1849 it is said that Heath owed the East India Company Rs. 8¼ lakhs. In 1849, a new company called the East India Iron Co. was formed with a capital of £400,000 to take over the previous concern and they settled the East India Company's claims by paying them £10,000. This new company erected blast furnaces at Tiruvannamalai (in North Arcot) and Pulampatti (on the Cauvery) in 1853. This concern had also to stop operations by 1858 at Pulampatti, by 1866 at Porto Novo and by 1867 at Tiruvannamalai, and went out of business in 1874.

The blast furnace at Pulampatti used the high grade 'float' ore at the foot of the Kanjamalai which was 28 miles away, charcoal

being derived from the forests near Kovil Cholapadi (11° 54′:77° 52′) on the Cauvery a few miles above Pulampatti. It is stated that the cost of ore and charcoal delivered at the works was around Rs. 7 and Rs. 8 respectively and that the output of iron was around 50 tons per week. The cost of the manufactured iron at Pulampatti and Porto Novo are reported to have been around Rs. 40 and Rs. 56 per ton respectively.

Trials were made in England in 1903 on Salem ore and Sanctoria coal from Bengal. The yield of iron was low and the ore was pronounced unsuitable for the blast furnace.

Previous work

The earliest references in English to the iron industry in this province are to be found in the accounts of journeys by officials of the East India Company and other travellers. Amongst these are the writings of P. M. Benza (1836), T. J. Newbold (1845), and E. Balfour (1855); the last has brought together all the available information regarding the distribution of ores, etc. Several papers by other authors—Campbell, Garstin, Maylor, Heath, Prinsep—have also been published on the industry established in Salem, North Arcot, South Arcot and Malabar.

The first comprehensive geological account of the Salem-Trichinopoly region was published by W. King and Bruce Foote in Vol. IV of the Memoirs of the Geological Survey of India in 1864. The Salem district Gazetteer (1883) by Le Fanu gives a summary of the information on the iron industry of the district. Mr. T. H. Holland (later Sir Thomas H. Holland) examined the deposits in Salem between 1890 and 1892 and a report thereon was published as a handbook of the Imperial Institute in 1893. Mr. C. S. Middlemiss examined the Kanjamalai a few years later (1896), as also Dr. W. Chowdhry on behalf of a private firm (Messrs. Gaudart et Cie. of Pondicherry) in 1905. Both these investigators showed that the ores as such were poor in iron content (around 35 per cent. iron).

In 1919, Dr. M. Stuart of the Geological Survey of India was deputed, at the instance of the Government of India, to collect bulk samples from the Kanjamalai for concentration tests at Dhalbhumgarh in Bihar. Unfortunately the ore was crushed only to 3/8 inch size, which was not fine enough to yield a good separation by the electro-magnet. The improvement in iron content in the concentrate was insignificant for it is now known that the average ore needs crushing to 10 mesh. A few years later, the Government of Madras sent some crushed samples to the Travancore Minerals Co. in Travancore for concentration tests. The tests were not successful and it is stated that the magnets in the Company's works were far too

powerful for such a highly magnetic material as magnetite and therefore attracted also the associated minerals. There is, however, no doubt, as proved by laboratory tests in recent years, that the ore is amenable to magnetic concentration if crushed reasonably fine (*minus* 10 mesh) and if a weak field is used. This has also been proved in some tests with bulk samples sent to Germany by Messrs. Gaudart et Cie. Dr. V. S. Dubey and Mr. C. Karunakaran of the Benares University investigated the Kanjamalai ores in 1937-38 on behalf of the Government of Madras.

A fairly detailed examination of most of the deposits in the Salem-Trichinopoly region has been conducted during 1940-42 by Mr. N. K. N. Aiyengar. The results have been published in the Fort St. George in 1944.

During the War period, the deposits near Veldurti and Ramallakota in Kurnool and near Chabali in Cuddapah have also been examined by the Geological Survey of India.

Distribution

VIZAGAPATAM

A general account of the former iron industry in this district is to be found in the Gazetteer of the district by D. F. Carmichael.

Hematite-breccia is said to occur at Chitra (19° 4′: 82° 27′) in which the matrix is good hematite. This formation has, in former times, been mined over a distance of a mile. Magnetite-quartz-schists are found near Modpodor (18° 46′ 30″: 82° 20′) while limonite masses, possibly superficial, occur at Bagchua (19° 2′: 82° 25′). Hematitic ore is said to have been mined formerly near Narainpatam (18° 52′ 30″: 83° 11′).

WEST GODAVARI AND KISTNA

Blanford states that quartzites and gneisses occurring to the south of Polavaram contain streaks of interlaminated magnetite. Limonite patches in the Rajahmundry and Golapilli sandstones have also been dug up and used.

GUNTUR

Lateritic ore (limonite) occurs in parts of this district and has been utilised formerly for making iron. There are also some bands of quartz-magnetite rocks in this district.

CUDDAPAH

(a) *Chabali.*—C. A. Oldham (*Memoirs, G. S. I.*, VIII, p. 172, 1872) first examined an occurrence of hematite near Chabali (14° 30″: 78° 36′)

and stated that "the ore is very abundant, covering at least a square mile and coming well to the surface". After a recent examination, Mr. K. K. Sen Gupta (*Q. J. Geol. Min. Met. Soc., India*, XV, March 1943) stated that large quantities of ore were available but his estimates appear to be rather exaggerated.

The rocks at Chabali are the Vempalle limestones overlain by quartzites (? Pulivendla quartzites) intercalated with ferruginous quartzites and shales. The ferruginous quartzites are locally enriched to iron. The ores occur in the Tummaleru Extension Reserved Forest about 1 mile south of Chabali being irregularly distributed and often looking like laterite at the surface. The largest patch is just to the west of the pond called *Salla-neelu-kunta*, while a smaller one lies S 30° W. of Chabali.

In the large patch there is an excavation 70 ft.×20 ft. and 8 to 11 ft. deep. The upper portion is bedded and shaly, and the lower massive, but fairly soft hematite. Another pit lies some 50 yards NNE of the above and measures 40 ft.×30 ft.×3 ft. A group of small pits is seen 1 furlong NW of the large excavation.

A dozen shallow pits were put down in the area under the supervision of Mr. M. S. Balasundaram of the Geological Survey of India. The samples taken therefrom gave iron content varying between 54·06 to 65·55 per cent. (average of 7 samples 62·82 per cent. Fe). Mr. Sen Gupta has given two analyses of ore taken presumably from the large pit.

	a	b
	(per cent.)	(per cent.)
Iron	65·17	64·44
Silica	5·10	3·45
Alumina	0·45	1·75
Phosphorus	0·69	0·09
Sulphur	—	0·09
Manganese	—	0·02

The ore is shaly in texture and chocolate coloured. Some of it is comparatively soft and can be used as a paint pigment. The ore is distributed in shallow patches and has been derived from the enrichment of shales and ferruginous quartzites of the Pulivendla quartzite formation. The large excavation is estimated to contain some 40,000 tons of ore of which a large part will be suitable for use as a pigment.

(b) *Pagadalapalle* (14° 27′: 78° 37′ 30″)—Half a mile west of Pagadalapalle and near mile 14½ on the Cuddapah-Pulivendla Road, patches of iron ore of the same type are seen, especially in *nala*

sections. The frequency of the presence of debris strewn on the surface here gives a false impression of great abundance. The *nala* sections show ore only to a depth of 5 ft. or 6 ft. Some prospecting pits seen in this area do not seem to have given any encouraging indications. The area may contain a few thousand tons distributed in shallow patches. Two analyses given by Mr. Sen Gupta are given below:

	1 (per cent.)	2 (per cent.)
Fe_2O_3	86·00	85·93
FeO	1·09	0·69
SiO_2	4·55	6·51
Al_2O_3	5·97	3·35
TiO_2	0·13	*nil*
CaO	*nil*	0·20
MgO	*nil*	0·60
P_2O_5	0·16	0·19
SO_3	*nil*	Tr
Alk	0·40	—
Loss ign.	1·85	2·12
Moisture	0·20	0·39

(c) *Pendlimarri* (14° 27′: 78° 38′ 30″)—About 2½ miles south of this place, which is about 12 miles west of Cuddapah, the quartzite formation shows veins of quartz containing specular iron ore, from which lumps of ore have weathered out. The quartzite, though ferruginous in places, cannot be worked economically as the quantity of ore available is insignificant.

(d) *Mantapampalle* (14° 19′: 79° 5′)—Ferruginous quartzites occur 1½ miles north of this village and have given rise to small lumps and segregations of iron ore. Similar material occurs also SSW and WSW of Erranguntlakota (13° 58′: 79° 17′).

KURNOOL

Bands of ferruginous quartzite have been worked on the western slopes of the Nallamalai range between Nandyal (15° 29′: 78° 37′) and Nandialampet (14° 43′: 78° 49′). The indigenous smelting industry as practised at Rudravaram and other places here has been described by Wall.

Several deposits of good hematite occur along a fault zone passing through the neighbourhood of Veldurti (15° 34′: 77° 56′) and Ramallakota (15° 34′: 78° 0′ 30″) in a E.-W. direction cutting across the basal Cuddapah formations. The ore bodies form hillocks with a general ENE-WSW trend and a steep dip towards NNW. The ore is hematite

of good quality, partly specular in character, but there is also some jaspery and siliceous hematite with it. The chief deposits are mentioned below. Of the total quantity of ore in each, 20 per cent. has been assumed to be of good quality (except in 3, 4, 8 and 9 where a larger percentage is assumed) and the reserves of good ore only are given here.

	Reserves (tons)
1. Veldurti—hillock ·1395 south of the village (600 yds.×70 yds.)	540,000
2. Two miles from Veldurti on Ramallakota Road (200 ft.×20 ft.)	8,000
3. Brahmagundam hill (mile 2½ on the above road). Two bands of ore are exposed on this, 1,000 ft.×250 ft. and 1,000 ft.×250 ft.	866,000
4. Ridge on Ramallakota-Boyanapalle Road. The ore body on top of the ridge is good while the one at the western end is siliceous	240,000
5. Gani Ghattu hill—western end (800 ft. long) . . .	48,000
6. Gani Ghattu hill—between hill . 1840 and deposit No. 5 Ore body 700 ft. long	56,000
7. Gani Ghattu hill—intersection of Sarafarajapuram path—small body 100 ft.×30 ft.	6,000
8. Gani Ghattu hill—conical hillock north of peak . 1840 .	
9. Low ridge 1 mile SE of Ramallakota and north of Gani Ghattu	180,000
10. Near mile 8 on Ramallakota-Kalava Road (1200 ft.× 500 ft.)	1,500,000
TOTAL . .	3,714,000

There is a considerable quantity of 'float' ore strewn on the surface east of No. 9 but it is not known whether it is underlain by a good ore body. Samples collected from the various ore bodies showed iron content varying between 48 to 65 per cent. with low phosphorus and sulphur (both of the order of 0·008 to 0·01 per cent.). The ore appears to have been deposited in a fault zone by hydrothermal agency. There is much siliceous ore accompanying the good ore.

The Pulivendla quartzites half a mile NW of Guttupalle (15° 25′ 30″ : 78° 3′) near Rangapuram Railway Station are ferruginous and contain lenses and lumps of ore which is usually soft and can be made use of as a paint pigment. This deposit may yield a few thousand tons.

Ferruginous quartzites occurring on hillock ·741 west of Devarajughatta (15° 48′ : 79° 15′ 30″) and occupying the cleavage planes of Cumbum slates contain some poor ore. Similar ore occurs also in a hillock (·581) 2½ miles NE of Gajjalakonda (15° 45′ : 79° 23′ 30″).

BELLARY

Foote has noted the existence of several deposits of ferruginous quartzites and iron ore in the Sandur mountains, Copper mountain, Mallapanbetta, Kalhalli Sodda, Teligi hills, Sindigiri hills and near Timlapur and Yellapadurga. Most of these are of little importance but the Sandur mountains contain very good deposits.

Sandur State is occupied by a series of folded ranges (thought to be a synclinorium) composed of pre-Cambrian phyllites, hematite-quartzites and basic igneous rocks. The hematite quartzites and the associated phyllites have given rise to iron and manganese ores by enrichment, these ores being found as a capping of comparatively small thickness (about 100 to 200 ft.). The average iron ore contains 55 to 65 per cent. iron, 0·01 to 0·1 phosphorus and 0·01 to 0·2 sulphur. Mr. M. S. Venkatram of the Geological Survey of India who investigated these deposits has made the following estimates of ore available within 50 to 80 ft. from the surface.

	Reserves (million tons)
Donimalai range	26
Devadari range	15
Kumaraswami-Kammadheruvu	25·5
Kanavehalli range	0·5
Ramandrug range	30
Timmapanna Gudi range	33
	130

NELLORE AND GUNTUR

Both magnetite- and hematite-bearing schists occur in these districts. According to Bruce Foote, there are two groups of occurrences of magnetite-quartzites—the Ongole group and Gundlakamma group. The Ongole group occurs 15 miles north of Singarayakonda and comprises 4 beds in the Konijedu hills. Some other beds also occur in the hills north-west of Ongole and in the Parnametta hill, 4 miles NW of Ongole. These two sets probably form the arms of a folded group.

The Gundlakamma group consists of 4 or 5 subgroups stratigraphically related but geographically separated from each other. These are:

(*a*) The Burapalle group consisting of two thick and fairly rich beds which are apparently connected with the beds exposed in the Tammavaram hill, two miles to the north-west.

(b) The Manikesvaram band which is more than 1 mile long, 1½ miles NNW of the above.

(c) A group of five beds in the ridges 2 miles north of Addanki. Three of the bands are moderately rich in magnetite and form the Singrikonda. They dip eastwards at high angles.

(d) Four other bands are seen 4 miles NW of Singrikonda, near Vemparala. They may really be parts of only 2 bands.

Several beds of hematite schists, intercalated with micaceous and flaggy schists, occur in the Chundi hills west of Polenane Cheruvu. Two of these are richer in iron than the others.

NORTH ARCOT AND CHITTOOR

Beds of magnetite-quartzite, usually rather poor in magnetite, occur near Gudiyattam, Katpadi and Vellore (Foote: *Rec. Geol. Surv. Ind.*, XII, Pt. 4, p. 193), and also in the Periyamalai near Polur. These are too poor to be utilised economically.

Ironstone is said to have been mined in the Sannamalai hill in the Arni taluk and from near Polur and used formerly in small indigenous furnaces, of which some 200 were in existence in this area a century ago.

SOUTH ARCOT

Numerous exposures of magnetite-quartzite have been found by King and Foote (*Mem. Geol. Surv. Ind.*, IV, p. 223-386, 1884) in the northern and eastern parts of the Kalrayanmalai. Important beds have been noted near Sankarapuram (11° 53′: 78° 46′), Chinna Tirupadi (11° 43′: 78° 49′) and Madur hill (11° 45′: 78° 44′).

The blast furnaces erected at Porto Novo in 1830 and at Tiruvannamalai a few years later were presumably fed by ore mined in the district. Accounts of the smelting operations have been published by Garstin and Maylor.

CHINGLEPUT

Holland has stated (*Imp. Inst. Handbook*, No. 8, 1893) that a bed of magnetic ore 3 ft. thick occurs about 1 mile south of the Sub-Collector's bungalow at Chingleput (12° 42′: 79° 59′).

SALEM-TRICHINOPOLY

A fairly good account of the geology and the iron ores of this region was given by King and Foote in the Memoir published in 1864. Sir Thomas Holland investigated the ores in the nineties and

found that some of them were of very high grade. A few years later, Mr. C. S. Middlemiss collected samples from the lowest bed in the Kanjamalai and found that the iron content was generally between 35 and 40 per cent. (*Rec. Geol. Surv. Ind.*, XXIX, p. 38, 1896). The average analysis of the samples was iron 39·02 per cent.; silica 42·3; sulphur 0·03; phosphorus 0·13 per cent. Dr. W. Chowdhry who examined the Kanjamalai in 1905 on behalf of Messrs. Gaudart & Cie of Pondicherry also found the average grade to be the same. A bulk sample of 5 tons sent to London by this firm gave the following analysis: Iron 44·2 per cent.; alumina 11·86; silica 22·25; titania 1·92; lime 1·92; magnesia 0·72; phosphorus 0·123; sulphur 0·021 per cent.

Dr. V. S. Dubey and Mr. C. Karunakaran of the Benares University conducted another field examination of the Kanjamalai in 1938 on behalf of the Madras Government. According to them, the ores contain 45-55 per cent. magnetite and 35-50 per cent. silica (*Q.J. Geol. Min. Met. Soc. Ind.*, XV, pp. 3-20, 1943). Dr. Dubey has advocated the smelting of the ores by electricity and has given an estimate of cost which appears to be too low even for pre-War days.

There are numerous deposits of magnetite-quartzite in the Salem-Trichinopoly region, which were mapped in recent years by Mr. N. K. N. Aiyengar. The bands of magnetite-quartzite are intercalated with mica-schists, chloritic schists, garnetiferous amphibolites and gneisses. The magnetite-quartzite is the metamorphosed equivalent of the original sedimentary beds which were hematite-quartzite. A little hematite and amphibole are sometimes found intimately associated with the magnetite.

Short descriptions of the more important deposits follow:

1. *Kanjamalai* (11° 37′: 78° 3′ 30″).—This hill, situated at a distance of 4 miles west of Salem, has an elliptical outline and measures 4½ miles (E-W) by 2½ miles (N-S). It is basin-shaped in structure and contains three major bands of magnetite-quartzite which can be traced right round the hill. The lowest band, at ground level, is 100 ft. thick, while the other two are 30 ft. thick each.

2. *Godumalai* (11°41′: 78°20′).—Godumalai is 11 miles to the east of Salem. It is 4½ miles long and contains a thick band forming the cliff ·2894 which splits up into two branches to the east. The major part of the reserves are in the cliff and to its west.

Agraharam.—North-east of this village is a band 200 yds. long, though much of this is rather high in silica.

Sarkar-Nattarmangalam.—West and south-east of this place are two bands each 100 yds. in length.

South of Godumalai.—There are a number of bands east and south of Godumalai, of varying length and thickness.

Singipuram hill ('1373) shows three bands of magnetite-quartzite with an aggregate thickness of 60 ft.

Puduppalayam.—A band about 1 mile long and 30-60 ft. wide is seen crossing the Valappadi-Singipuram Road about 3 furlongs SE of Puduppalayam. There are also other exposures in the neighbourhood.

3. *Attur*.—A band 25 ft. thick on an average is seen on the northern flank of hill ·2013 trending SE for 1½ miles.

Thammampatti.—There are several bands of magnetite-quartzite in this neighbourhood, and especially on hills ·1668, ·1717 and ·1093.

Singiliyankombai.—North and south of this village are 4 or 5 bands of ore, on hills ·2194, ·1564, ·1706 and ·1516.

4. *Tainandamalai and Chitteri hills*.—There are numerous important bands in these hills, near the villages Belur and Sittilingi.

Belur area.—The Godumalai band apparently continues into hill ·1609 and a branch of this goes on to Kurichchi. Parallel to this are a few bands near Andiyur, Idaiyappatti and Vellalappatti.

Sittilingi area.—Three important bands are seen—WNW of Sittilingi, west of Malatangi and near Tekkalpatti.

5. *Tirthamalai*.—There are four important bands in these hills. One of these is 4 miles long and trends NNE from SW of peak ·3220, going into the Elavambadi R. F. The second is parallel to this, forming peak ·3220, and going beyond Tumbal. The third is an offshoot of the second, while the fourth is found at the SE base of the hills half a mile south of Andiyur.

Modukuli.—A mile to the south-east of this village there is a band ¾ mile long and 30 ft. thick. A similar band is seen north-east of Alambadi.

6. *Rasipur-Namakkal area*.—There are half a dozen bands, a furlong to 4 furlongs in length, near Pattanam and Puduchatram. Larger bands, six, three, six and four miles in length respectively, are noted near Belukkurichi, Namagiripettai, Narasimhapudur and Kondamanayakanur.

7. *Kollai malai*.—Two bands are noted, ½ mile and 2 miles in length respectively, near Tottikadu and Valavandi. A few other bands are seen around Kirambur.

Villiyappanpatti-Tattayyangarpettai.—The main band in this area can be traced over a length of nearly 25 miles from west to east, parts of which are fairly rich in magnetite. There are 4 or 5 bands south of this, all of which contain some good ore.

Mahadevi hill.—In and in the neighbourhood of this hill are at least half a dozen bands of fair quality ore. One of these is 3½ miles long.

8. *Pachchaimalai.*—A 6-mile long band is to be found north of Ladapuram and a few shorter ones near Kanavoy and Elambalur.

The reserves given below refer only to the more conspicuous and richer bands of ore in which the magnetite content is more than 25 per cent. In all cases (except in a part of the Godumalai) the depth of the ore-body assumed is 100 ft. from the outcrops.

		Tons.
1.	Kanjamalai	54,648,000
2.	Godumalai	12,450,000
	Perumamalai-Puduppalayam	10,428,000
3.	Attur-Singiliyankombai	11,724,000
4.	Chitteri & Tainandamalai	55,416,000
5.	Tirthamalai	47,520,000
6.	Rasipur-Namakkal	33,924,000
7.	Kollaimalai	67,452,000
8.	Pachchaimalai	11,088,000
	TOTAL	304,650,000

The reserves are computed on a conservative basis and it is almost certain that, in actual working, the available ore from these deposits will be 2 or 3 times the amount shown above.

The ores are mainly mixtures of magnetite and quartz in varying proportions. Occasionally a little hematite and amphibole of the grunerite group are present. The sulphur content is low and phosphorus variable, and the latter may be reduced by crushing and magnetic concentration of the ore. The greater part of the ore is rather coarse grained and gneissic in texture. Occasionally the coarse material contains lumps of pure magnetite which are weathered out and strewn over the outcrops. Some of the ore is very fine grained, in which the constituents are not separately distinguished by the naked eye ; sometimes however the uniformity of appearance is broken by clots and streaks of quartz or magnetite.

Numerous samples were collected from the various outcrops, but only about 40 were analysed. In the analyses the silica varies between 45 and 55 per cent., iron (metallic) between 35 and 40 per cent., phosphorus between 0·03 and 0·15 per cent. The ores are amenable to magnetic concentration as proved by laboratory experiments. For getting a good separation the ore has to be crushed to 10 mesh or finer. The concentrates analyse 55 to 66 per cent. iron.

Since similar ores are worked in the New York State successfully, they are worth further investigation in regard to concentration and smelting. Lack of coal in South India makes it necessary to investigate the feasibility of utilising electric power for smelting.

COIMBATORE

According to Sir Thomas Holland, magnetite of good quality is said to occur in the Kollegal taluk and a rich bed of the mineral is known in the Doddancombai forest, Satyamangalam taluk.

Quartz-magnetite schists form a hillock near Hallagomalai and are also found in the Chennimalai near Erode (*Rec. Geol. Surv. Ind.*, XXIX, p. 152).

MALABAR

The following localities are mentioned by P. Lake and Sir T. H. Holland as containing some iron ores; Hematite-gneiss 1½ miles SW of Nilambur (11° 17′:76° 17′); garnetiferous gneiss with bands of hematite, 6 miles ESE of Wandur (11° 12′:76° 16′); friable iron ore 9 miles E of Wandur; bands of ferruginous gneiss 1 mile E of Porur (11° 9′ 30″:76° 17′); hematite-gneiss 2 miles SE of Yadakurichi (10° 57′:76° 32′); gneiss with magnetite near Nemini (11° 3′:76° 14′).

NILGIRI

The most important iron ore bands in this district are, according to H. F. Blanford (*Mem., Geol. Surv. Ind.*, I, pp. 219-248, 1858), near Karachola, 1½ miles W of Kotagiri (11° 24′ 30″:76° 53′) on a spur of the Dodabeta. It is not known whether these are of any economic importance.

PUDUKKOTTAI STATE

Bruce Foote has noted the occurrence of a bed of magnetite in gneiss about 1 mile NE of Mallampatti (10° 36′ 30″:78°41′). Lateritic ores from Tertiary sandstones at Ayangudi (10° 21′ 30″:79° 0′) and other places were formerly smelted in indigenous furnaces.

Prospects

Though numerous deposits have been referred to in the previous pages, only the magnetite-quartzites of Salem-Trichinopoly and the hematite ores of the neighbourhood of Veldurti and Ramallakota have been examined in recent years and are worth further attention. Until all the districts are systematically examined, we cannot say whether there are any other important groups of deposits.

Much attention has been bestowed on the magnetite ores of Salem during the past century. The first attempt at smelting them at Pulampatti was a financial failure, one of the reasons being that the people concerned wanted to market the iron in England. Later attempts were all more or less half-hearted and partial. One of these was by a French firm of Pondicherry (Messrs. Gaudart et Cie) who

sent bulk samples to England and Germany for testing. In the latter country, the famous firm of Krupps conducted experiments on magnetic concentration and are said to have pronounced them easily amenable to the process, with a great improvement in the iron content. It is high time that the question of proper utilisation of these ores is taken up in earnest and experiments conducted under expert supervision in order to gather the necessary economic data for assessing their importance.

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CHAPTER XXV

KYANITE AND SILLIMANITE

Kyanite, sillimanite and andalusite form a group of aluminium sillicates of the same composition ($Al_2O_3.SiO_2$) but differing in their crystallographic and physical properties. Kyanite occurs in bladed triclinic crystals of a blue colour which are softer in a direction parallel to their length than perpendicular to it. Its specific gravity is 3·6. It is fairly resistant to acids.

Sillimanite occurs in needle-like crystalline tufts or aggregates having a white, greyish, greenish or brownish colour. It crystallises in the orthorhombic system and has a specific gravity of 3·24-3·34.

Andalusite is white, grey, pink or violet in colour, orthorhombic in crystallisation, and of prismatic habit. Its specific gravity is 3·2. It often contains inclusions and shows zoning parallel to the vertical axis.

All these minerals occur as constituents of crystalline schists derived from aluminous sediments. Andalusite is thought to indicate a lower grade of metamorphism than the other two. They contain 63·2 per cent. of alumina when pure but the closely associated impurities may reduce this percentage. Occasionally, if intimately mixed with corundum, the alumina may be higher than the theoretical percentage.

Uses

On heating, all these minerals are converted into mullite ($3\ Al_2O_3 \cdot 2\ SiO_2$) at a temperature of 1540° C. Mullite is a very stable refractory and does not undergo any chemical change or shrinkage on further heating, up to about 1810° C. when it begins to soften. It is also resistant to oxidation and reduction by acid or alkaline slags and is therefore a much-prized refractory especially valuable in glass melting furnaces. Mullite also gives a hard dense ceramic body with high electrical resistance which makes it useful for the manufacture of electricporcelain (*e.g.*, spark plugs). Calcined kyanite, sillimanite and andalusite are ground and shaped with a binding material into glass pots and tanks, retorts, crucibles, saggers, muffles, etc. They cannot be used in metallurgical furnaces since basic and metallic slags attack mullite.

Distribution

KYANITE

Coimbatore.—Middlemiss has mentioned the presence of small quantities of kyanite in the area of the corundum pits near Kanjikovil (11° 22′ 30″ : 77° 36′).

Nellore.—A small deposit occurs in the mica schists of the hillock just north-west of Saidapuram (14° 10′ 30″ : 79° 44′ 30″) in the Nellore mica belt. The mineral is found in pockets and lenses, over a length of 200 yards. Though the deposit has been taken on lease by someone, it has not been opened up. It may probably yield a small tonnage.

Kyanite occurs in association with quartzites and quartz schists near Chundi Chattram (15° 6′ : 79° 38′) in a series of ridges striking NNE-SSW, terminating at the Malekonda hill (·770). The country rocks are garnetiferous kyanite and staurolite schists containing numerous quartz veins. The rocks dip to the SE at high angles. Kyanite occurs associated with quartz forming lenses up to 20 feet long, lying more or less parallel to the schistosity. Workable lenses occur on the eastern margin of ridge ·712, on the western and northern slopes of ·770, in the northern half of the Chundi ridge and between milestones 19 and 20 of the road passing through here. The lenses pinch out at a depth of a few feet but there are indications that other lenses appear further down. The deposits are very irregular and may contain perhaps 2,000 tons of kyanite within a depth of 10 feet. The area deserves detailed prospecting.

SILLIMANITE

Sillimanite is frequently an essential constituent of the khondalites which occupy extensive areas in the Eastern Ghats of Vizagapatam, East and West Godavari and Kistna districts. But no deposits containing a sufficiently rich concentration of sillimanite for working has been reported.

Sillimanite-bearing schists also occur, in association with crystalline limestones, in the hills near Madukkarai (10° 54′ : 77° 58′) a few miles south of Coimbatore.

The mineral is a constituent of the beach sands of Travancore containing ilmenite, monazite, etc. During the concentration of these sands, sillimanite goes into the tailings from the gravity tables on which monazite is separated. The tailings containing sillimanite and much quartz are treated on wet tables so as to increase the percentage of the mineral to around 50 and then put through flotation cells which give a concentrate containing 85-90 per cent. This can be concentrated further by the elimination of the associated quartz, zircon and rutile by repeated tabling. A small tonnage of sillimanite concentrate has been recovered by the Travancore Minerals Co. since 1936, according to Mr. P. Viswanathan.

This is of interest since some parts of the Madras Coast also contain workable, though comparatively small, deposits of heavy mineral sands which may yield sillimanite. The presence of this mineral in the sands of the Madras Coast has been confirmed.

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CHAPTER XXVI

LEAD

The most important source of lead is the mineral galena (PbS). It is often associated with other sulphides, notably those of zinc and silver, and sometimes antimony, arsenic, etc. Lead deposits often contain, in the zone of oxidation, two other common lead minerals, cerussite ($PbCO_3$) and anglesite ($PbSO_4$).

Lead ores occur as veins occupying fissures and planes of weakness of earlier rocks or as replacement bodies in limestones and dolomites. The common associates of lead ores are quartz, barite, siderite, pyrite and often other sulphides. They are considered to have been derived from hydrothermal sources and deposited at comparatively low temperatures.

Uses

Metallic lead is soft and malleable and resistant to acids. But, being slightly soluble in water, its use as such is rather restricted for many purposes as lead compounds are highly poisonous to human beings. It is, however, widely used in industry, both as metal and its alloys and in the form of compounds. The metal is used in storage batteries, cables, in plumbing and in chemical plants. White lead (basic lead carbonate), red lead and litharge (oxides) are widely used as paints. Some of the alloys are used as solders and others in the manufacture of shots and type-metal.

Distribution

Lead ores are known to occur in a few places in Guntur and the Ceded districts. The deposits have been mined in former years and only the disused pits and quarries are to be seen at present.

Kotlur (14° 36′ : 78° 45′) is a village situated on the Penner, about 13 miles from Cuddapah town. An old excavation is noticed about 100 yards west of the village on the bank of the river. The country rock, a siliceous limestone, is traversed by quartz veins containing the ore. Another excavation is found about a furlong N.N.W. of Kotlur, this being about 100 feet long in a N.W.-S.E. direction which is also the strike direction of bedding of the country rock. It is reported that some years ago a small vein in the river yielded some ore, but little or no ore is seen in the excavations or in their neighbourhood.

Nagasanapalle (14° 42′ : 78° 49′) is situated on the Cuddapah-Badvel road to the west of the Lankamala hills. P. W. Wall has noted that good ore occurred in a branched vein exposed south-east of Nagasanapalle. The vein, which was 4-5 inches wide, was estimated to yield 18 cwt. of dressed ore per yard length. Samples from this yielded 70-76 per cent. lead on assay.

Dr. B. C. Roy who examined this area in 1944 found an excavation on the hill slopes, 2½ miles S.E. of the village. This excavation is presumed to have been made by some prospectors in 1935. The country rocks are slaty shales which are traversed by quartz veins showing specks and streaks of galens. The surface indications are very poor.

Zangamrajupalle (14° 46′: 78°53′) is situated in the Nallamalai hills and can be reached by cart track from Nagasanapalle. Newbold described the occurrences here in 1842 as comprising some 50 pits, some of considerable depth. The best known excavations are 2½ miles S.W. of the vilage while others are found at the end of a low ridge N.N.E. of the village. The country rock is a limestone associated with slaty rocks, these being traversed by blue and white quartz veins, the former containing disseminations of galens. Newbold has stated that the veins were up to 1½ inches in thickness and there were also pockets of ore, the cavities being lined with quartz and iron oxide. P. W. Wall, who examined this area in 1858, states that indications of ore could be traced for a distance of 4 miles. King examined this locality during his survey of the Cuddapah formations. According to him the limestones are of Cumbum age and some ore occurred also in the quartzites to the west of the village. No good ore was found by him *in situ* but the old drumps showed the presence of galena. King was also shown some fine specimens by Col. Maberly, Superintending Engineer of the district at the time.

The limestones of the small ridge north-east of the village can be followed for some distance in a southwesterly direction, along the strike of the formations. The quartz veins are up to 12 inches thick, and though barren of ore, contain stringers of ferruginous matter. Though little or no ore is seen at the surface at present, the veins may contain ore at some depth.

Koilkuntla (15° 13′: 78° 19′).—Old workings are said to have been present at a distance of a quarter of a mile from this village in an area which is now entirely under cultivation.

Wall conducted prospecting operations here many years ago and estimated the yield of ore as 9 cwt. per fathom. Samples of ore are said to have assayed 12 to 14 oz. silver per ton of lead.

Basavapuram (15° 24′: 78° 38′).—This is a hamlet of Gazulapalle on the western flanks of the Nallamalais on the Nandyal-Giddalur road, near the entrance to the Nandikanama pass. The mines are at a distance of 8 to 10 miles from Gazulapalle. The old excavations have been described by Capt. Newbold in 1846, the ore being found in quartz veins associated with barytes, traversing slaty rocks. Wall, who conducted some prospecting operations here, states that his

samples yielded 57·5 per cent. lead and 5 oz. 19 dwt. of silver per ton of lead. Dr. King who visited the area later found only poor traces of ore in veins running N.N.E.-S.S.W.

There are two groups of excavations here. The larger group is about 1 mile S.E. of Chelima railway station, and extends E.-W. for some 400 yards. The other set of exacavations is 6 furlongs west of the first set (and S.W. of Chelima). They are all in calcareous shales and slates striking N.N.E.-S.S.W. and dipping towards E.S.E. at high angles. The bedding planes and joints are traversed by quartz veins containing granular disseminations of galena. The present indications are very poor, all the better material having been removed years ago.

Chityala.—This occurrence is half a mile from Kollakonda, a hamlet of Chityala, which can be reached from Malyala railway station (Kurnool district) on the Dronachalam—Guntakal section of the M. & S. M. Railway. One large and three small exacavations are found here, the first being 20 feet × 20 feet × 15 feet. Some galena is noticed in the debris.

Wall seems to have prospected this deposit. He found some large masses of ore in the veins. Some 25 years ago, the late Mr. A. Ghose, well known for his mining activity in the Ceded districts, conducted prospecting operations and obtained some ore though the results were unencouraging.

According to Dr. B. C. Roy, the country rock is a coarse grained grey granite traversed by quartz veins. It would appear that the ore occurred in a fault-breccia of quartz traversed by a network of secondary quartz veins carrying a little galena and ferruginous material. There are at present no encouraging indications of ore. The fault breccia was not traceable in the smaller excavations, neither were there any indications of ore in them.

Karampudi (16° 26′ : 79° 44′).—In the northeastern extremity of Waumykonda range, in the Palnad tract of the Guntur district there are old workings just above the Karampudi village. The country rocks are grey and white limestones of the Cumbum stage. There are no encouraging indications of ore here.

Conclusion

It would appear that, at all the above places, there were fair indications of galena in the veins; when opened up, no persistent veins but only pockets were found. Some of the localities may be worth prospecting by shallow drill holes in order to see whether any veins occur down below.

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CHAPTER XXVII

LIGNITE AND PEAT

Introduction

Peat is considered to be the first stage in the formation of coal from vegetable matter accumulating in swamps. As the dead vegetation accumulates, it is shielded from atmospheric decay by the superincumbent material, and chemical changes take place thereafter under anaerobic conditions. Peat is formed at the present day in temperate moor lands, the widest distribution being between 30° and 60° north latitudes where the mean temperature is around 50° F. Peat beds are also found in the deltaic deposits of large rivers like the Ganges, and in the swamps of coastal plains.

Peat contains a large quantity of water ranging ordinarily from 75 to 85 per cent. Being very bulky, it is difficult to handle, but can be compressed and briquetted.

Lignite is the next stage in coalification, being either brown, in which the woody structure of plants is still clearly visible, or black, in which the plant structure is not so readily apparent. The moisture content of lignite ranges from 20 to 45 per cent., fixed carbon from 20 to 35 per cent., and the calorific value around 8,000 B.T.U. On exposure to air, it disintegrates rapidly and becomes powdery. It has therefore to be briquetted before use and has to be stored with care in order to prevent spontaneous combustion.

Uses

Both peat and lignite are low grade fuels and can be used for heating. Lignite has been used for almost all purposes for which coal serves, except that it does not yield hard coke suitable for metallurgical operations. Lignite has been extensively used in Germany in place of bituminous coal in various industries including the manufacture of motor fuel and power generation.

Distribution

PEAT

Nilgiri district.—Several peat bogs were reported to occur in the Nilgiri mountains at elevations of over 6,000 ft. and some of these were over 30 ft. deep. This peat was at one time used as fuel at Ootacamund. A. R. Wragge published an elaborate account of this and advocated the use of peat as fuel by the railways. ("On peat and its profitable utilisation in Indian locomotives and for other purposes." *Journ. Soc. Arts.* XIX, 201-208, 1871). No estimate has been made of the quantity available.

Tanjore.—In 1828, Mr. Nelson, Sub-Collector of Tanjore, reported to the Government that, at a spot near the promontory about 20 miles from Pt. Calimere. He found peat at a depth of 17 ft. from the surface and that the stratum consisted of dark clay full of vegetable remains in which the bark and branches of trees were distinctly visible. He also stated that this bed was much more than 5 ft. thick and that it extended perhaps along the coast for some 30 miles (Revenue Board's Consultations, dated 23rd October 1828, Vol. 1165, p. 10, 663-664). The Government, however, seems to have taken no action on this report.

LIGNITE

South Kanara.—In 1884, the Collector of South Kanara reported to the Board of Revenue that lignite was met with at Kasaragod at a depth of 30 ft. in one well and at 21 ft. in another well about a mile away, and that the bed in the first well was 2½ to 3 ft. thick. A sample of the lignite, examined by Bruce Foote, was pronounced by him to be of fair quality, though rather high in ash. Foote however seems to have communicated the opinion that it was unlikely that any large bed would be found in the district. (Revenue Board Proceedings No. 3935, dated 18th November 1884 and No. 1766, dated 15th November 1885). No further steps seem to have been taken about this discovery.

Malabar.—In 1830, General Cullen discovered a deposit of lignite at the base of the cliffs on the sea shore near Cannanore.

This was examined by Dr. K. Jacob of the Geological Survey of India in 1943. He states that the lignite bed is exposed at low tide over a length of several feet at the base of a 30-foot high cliff on the sea-shore about a mile north of Fort St. Angelo, Cannanore. The bed is 4½ feet thick, including a 3-inch layer of clay about a foot above the base. The upper portion of the seam at the sea-shore, on analysis, gave 28·2 per cent. moisture, 45·6 per cent. volatile matter, 13·4 per cent. fixed carbon and 12·8 per cent. ash, while the lower portion showed 40·3 per cent. ash. Though no other occurrence is met with for at least 2 miles on either side along the shore, there are records of finds in some wells about a quarter of a mile inland, at depths of 30 to 40 ft. It is not known whether there is any continuous seam.

Captain Newbold, in 1840, discovered lignite at the base of the cliffs of laterite on the river banks below the old Travellers' Bungalow near Beypore. It could be traced at intervals for about half a mile in an easterly direction. The bed varied in thickness from a few inches to 5 ft. and had a north-easterly dip at 4 degrees. The better parts of the seam consisted entirely of carbonaceous and woody matter, having a jet black to greenish black colour. The

associated black shale was found to be impregnated with aluminium sulphate, and to have a sulphurous odour. Newbold discovered lignite also on the banks of the Tirthala river in South Malabar. He thought that these occurrences might indicate a vast basin, the southern edge of which was at Varkala near Quilon where General Cullen had already (in 1832) discovered some lignite deposits.

Travancore.—General Cullen discovered lignite in the cliffs at Varkala (Warkilli or Vorkully) a few miles south of Quilon in Travancore State. According to King, who examined the occurrence some years later, the section of the cliff of Tertiary sandstone here is as follows, though it varies from place to place :—

	feet
Laterite	30-40
Sand and sandy clay or lithomarge	58
Alum clays	25
Lignite	7-18

Bruce Foote also examined the area in or about 1882 and confirmed King's observations.

The following details are taken from a report by Dr. C. S. Pichamuthu (*Bull.*, XXVI, Dept. of Industries, Travancore, 1927).

Lignite is exposed at several localities near Varkala on the shores of the Ashtamudi Kayal near Quilon and near Vaikom and Manavalakurichi. Near Varkala the cliff sections from near Kozhithotam to Thiruvambadi show lignite, the three prominent sections being near the Palace, Chilakoor and Vettur. In the Palace cliff, the carbonaceous bed is 20 ft. thick but of poor quality. On the road to the beach opposite the Palace, a good section is exposed for a length of 500 ft., with a thickness of 9 ft. The bed thickens to 20 ft. at the southern extremity, the upper 6 ft. being sandy and the lower 14 ft. clayey.

Analyses of samples from here gave :—

Moisture.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	13·8	15·46	13·50
On dried samples—			
Volatiles	35·34	42·05	32·80
Fixed Carbon	28·81	47·85	24·76
Ash	35·85	10·10	42·44

The Chilakur cliff section can be seen for a mile south of Papanasam, a good exposure being that along the steep descent from the road south of the temple to the beach, in a stream. The lignite here is sandy. In the Vettur cliff there is a 10-foot seam, about 20 ft.

above the beach. Samples from here contain high ash. There are indications of the presence of 3 or 4 seams in this area. In the Varkala neighbourhood lignite is expected to be found in an area of 20 sq. miles. Assuming the presence of 6 ft. of lignite in this area, the amount estimated is 100 million tons.

The Varkala beds occupy more than 500 sq. miles, the lignite being found only in certain parts of these. According to Messrs. Masillamani and Chacko, State Geologists to Travancore, the total estimated reserves of lignite in these beds are of the order of 276 million tons (Report of the State Geologists of Travancore for 1907 to 1910; p. 8, 53, 73). It is not known to what extent the lignite can be worked successfully and used as fuel.

Pondicherry.—M. Poilay, a French Engineer, reported the occurrence of two beds of lignite in bore-holes put down under his supervision at Bahur (11° 48′ : 79° 44′ 30″) five miles N.N.W. of Cuddalore, at Aranganur (2½ miles N. of Bahur) and at Kanniyakovil (3 miles N. of Cuddalore). An account of the results is given by King in a paper published in 1884 in the Records of the Geological Survey of India.

At Bahur the lignite seam was met with at 275½ feet depth and was 35 ft. thick. At Aranganur, a 27-foot seam was met with at 203 ft. and a 5¼-foot seam some 94 ft. further down. At Kanniyakovil, a 50-foot bed was encountered at a depth of 330 ft. From these it is calculated that the bed has a S.S.E. dip at 50 ft. per mile, on the assumption that the same bed has been touched in the three bore-holes. Some analyses of the lignite are given below :—

—	1	2	3	4	5
Moisture . . .	22·0	16·76	35·3	16·28	9·75
Volatile matter .	23·9	26·66	29·1	38·55	34·21
Fixed carbon . .	21·6	34·30	25·2	37·72	23·09
Ash . . .	32·5	22·28	10·4	7·45	32·95

The calorific value of the last two samples was 5,318 and 5,047 calories respectively. M. Poilay had seven samples analysed in Paris whose average ash was 8·35 per cent.

It is evident from the analyses that the material is liable to variation though this may, in part, be due to contamination from the associated strata because of the method of drilling employed.

In this paper King states that two beds of carbonaceous clays (apparently not lignite) were met with in borings put down for artesian water in the alluvial flats between Pondicherry and Cuddalore, but gives no details.

Pondicherry (artesian borings).—Some borings were sunk in Pondicherry town in 1877 which revealed the presence of carbonaceous and lignitic material in the strata.

1. *Savana boring* in the compound of the Savana Mills south-west of the town, just beyond the Uppar river and close to the Villianur road. Total depth 52·68 metres. Black clays were met with at 7·40 metres (2·88 m. thick), 10·66 m. (5·92 m. thick) and at 27·00 m. (6 m. thick).
2. *Oopalem boring,* south of Pondicherry.—Dark clay at 18·13 m. (16·97 m. thick).
3. *Jardin d' Acclimation* at the SW. corner of Pondicherry. Dark clays were met with at 8·15 m. (2·59 m.), 15·80 m. (11·30 m.), 28·40 m. (0·15 m.) and 44·75 m. (0·75 m). Remains of vegetation seen at 6·70 m., 12·02 m., 15·80 m., 67·9 m., 69·2 m., and 72·4 m.
4. *Ville Noire* (Black town or Indian town).—Black lignitic clays were met with at 14·04 m. (6·76 m.), 64·53 m. (0·91 m.) and 147 m. (1·10 m.). The one in the middle was fairly good lignite.

South Arcot district: *Neyveli field.*—Some 15 years ago the Department of Industries, Madras, put down several bore-holes in and around the Aziznagar Criminal Settlement (11° 31′ 30″ : 79° 26′ 30″) some 10 miles east of Vriddhachalam and one mile south of milestone 30 on the Cuddalore-Vriddhachalam road. All the bore-holes yielded artesian water and most of them are still in commission. Unfortunately the bore-hole logs were recorded by boring *mistries* who have described them indiscriminately, with the result that lignite is suspected to have been described as "black clay", "charcoal-like mud" and "hard black rock". Lignite was undoubtedly revealed in a bore-hole 265 ft. deep (11° 31′ 5″ : 79° 28′ 40″) sunk for Mr. Jambulinga Mudaliar in his property at Neyveli, for even to-day fragments of lignite are brought up by the vigorous artesian overflow of this well (which rises 10 ft. above ground through a 6-inch pipe and cascades 2 to 3 ft. above the top of this pipe).

A Madras firm who became interested in the lignite put down 4 or 5 bore-holes in the Aziznagar area, in two of which they definitely proved the existence of a lignite bed 30 ft. thick. They were not able to proceed with the investigation further owing to the difficulty of getting casing pipes and other drilling equipment during War time.

The Government of Madras learnt of the presence of lignite in this area and asked the Geological Survey of India to carry out drilling operations with two Calyx drills provided by their Public Works Department. Owing to the limited capacity of the drills, drill holes could not be carried down to more than about 300 ft. depth, and in several holes there was difficulty due to soft sands and clays and artesian water. With these limitations, 33 drill holes were sunk under the supervision of the writer, with Mr. R. N. P. Arogyaswamy in charge in the early stages and Mr. G. V. D. Upadhyaya in

charge in the later stages. Mr. G. Muthiyan of the Madras P. W. D. staff was the drilling foreman throughout the investigation. Except for 4 holes located along the Vriddhachalam-Chidambaram road, all the drilling was done in the area along and north of the Cuddalore-Vriddhachalam road in the neighbourhood of Neyveli (11° 32′: 79° 29′).

A summary of the result is given below. The co-ordinates refer to the actual sites of the bore-holes.

B. H. *1* (11° 32′ 30″ : 79° 28′ 40″).—Half a mile south of Neyvelli Railway station just east of the cart track.

Surface level 130·3 ft. Total depth 294 ft. Lignite from 232 ft. to 283½ ft. (51½ ft. thick) Carbonaceous clay 283½ to 294 ft. and artesian sands from 294 ft.

B. H. *2* (11 33′ 5″ : 79° 27′ 40″).—Half a mile N.W. of Vadakku-vallur and about ¾ mile S.S.W. of Toppulikuppam.

Surface level 120·7 ft. Total depth 171 ft. Lignite from 149 ft. to 171 ft. (22 ft. thick) Artesian sand below lignite at 172 ft.

B. H. *3* (11° 32′ 17″ : 79° 28′ 5″).—Just south of the Cuddalore-Vriddhachalam road at mile 27-6¼ furlongs, near Gangai-kondan village.

Surface level 95·4 ft. Total depth 232 ft. Lignite from 167 ft. to 201 ft. (34 ft. thick) Lignitic carbonaceous clay from 201 ft. to 227 ft. and below it artesian sand at 230 ft.

B. H. 4 (11° 33′ 10″ : 79° 28′ 35″).—About 2 furlongs north of Neyveli Railway station.

Surface level 122·5 ft.; total depth 205 ft.; lignite from 171 to 193 ft. (22 ft. thick); sandstone below lignite and artesian sand at 195 ft.

B. H. 5 (11° 32′ 15″ : 79° 27′ 15″).—Just south of Cuddalore-Vriddha-chalam road at mile 28—7 furlongs. Surface level 90·3 ft. Total depth 131 ft. Vigorous artesian overflow at 121 ft. No lignite.

B. H. *6* (11° 32′ 5″ : 79° 25′ 55″).—50 yards south of mile 30-3 furlongs on the Cuddalore-Vriddhachalam road, on the west bank of a small stream. Surface level 116·4 ft. Total depth 260 ft. No lignite. Artesian conditions met with at 91 ft. and 132 ft.

B. H. *7* (11° 33′ 0″ : 79° 25′ 45″).—Half a mile N.N.W. of Uttangal Mangalam railway station. Surface level 141·8 ft. Total depth 149 ft. No lignite.

B. H. *8* (11° 31′ 35″ : 79° 24′ 35″).—Just north of the Cuddalore-Vriddhachalam road at 31-7 furlongs. Surface level 130·8 ft. Total depth 150 ft. No lignite.

B. H. 9 (11° 33′ 40″: 79° 27′ 0″).—On the northern bank of the stream half a mile west of Toppulikuppam. Surface 152 ft. Total depth 260 ft. No lignite.

B. H. 10 (11° 34′ 35″ : 79° 26′ 30″).—Just N.E. of Melkuppam village, on the bank of a small tank. Surface level 197 ft. Total depth 160 ft. No lignite.

B. H. 11 (11° 34′ 0″ : 79° 28′ 35″).—Half a mile due north of the eastern end of Toppulikuppam, just east of a small tank. Surface level 146·9 ft. Total depth 199 ft. Lignite from 157 to 191 ft. (34 ft. thick). Carbonaceous clay from 191 ft. to 199 ft.

B. H. 12 (11° 34′ 15″ : 79° 28′ 35″).—3 furlongs west of Kuravankuppam. Surface level 158·3 ft. Total depth 195 ft. Lignite from 154½ ft. to 187 ft. (32½ ft. thick) Carbonaceous clay from 187 ft. to 193 ft. and sand below.

B. H. 13 (11° 35′ 0″ : 79° 28′ 10″).—2 furlongs south of Alandarkoliai. Surface level 188·2 ft. Total depth 252 ft. No lignite.

B. H. 14 (11° 35′ 0″: 79° 29′ 5″).—Eastern end of tank, 1 mile N. of Kuravankuppam. Surface level 184·2 ft. Total depth 206 ft. Lignite 187 ft. to 200 ft. (13 ft. thick). Carbonaceous clay from 200 to 203·5 ft. and below it sand.

B. H. 15 (11° 35′ 35″ : 79° 28′ 25″).—A quarter of a mile N.E. of Kovilkuppam and the same distance south of Payirveli. Surface level 201·5 ft. Total depth 189 ft. Sand and lignite 179 ft. to 180 ft. (1 foot thick). Sand below lignite.

B. H. 16 (11° 36′ 55″ : 79° 30′).—Eastern end of Permattur village tank. Surface level 211·3 ft. Total depth 205 ft. No lignite.

B. H. 17 (11° 35′ 30″: 79° 30′ 55″).—Just S.E. of Vadakkutteruvu. Surface level 162·6 ft. Total depth 216 ft. Lignite from 185 ft. to 210 ft. (25 ft. thick). Carbonaceous clay from 210 to 212 ft. and loose sand below this.

B. H. 18 (11° 36′ 15″: 79° 31′ 25″).—2 furlongs E. of Veludaiyanpattu. Surface level 151·1 ft. Total depth 213 ft. Lignite from 185 ft. to 206 ft. (21 ft. thick). Carbonaceous clay from 206 to 210 ft. and white sandstone below.

B. H. 19 (11° 36′ 10″ : 79° 33′ 5″).—Just west of milestone 121 on Vadalur-Panruti road. Surface level 160·2 ft. Total depth 297 ft. Sandy carbonaceous clay with lignite from 289 to 293 ft. (4 ft. thick). Loose sand below.

B. H. 20 (11° 35′ 15″: 79° 33′15″).—Just east of mile 122-2 furlongs on Vadalur-Panruti road. Surface level 103·3 ft. Total depth 249 ft. Carbonaceous clay with lignite from 241 to 244 ft. (3 ft. thick). Sands below and artesian water at 241 ft.

B. H. 21 (11° 33′ 55″ : 79° 29′ 35″).—2 furlongs W. of Terkukuppam. Surface level 136 ft. Total depth 209 ft. Lignite from 191 to 206 ft. (15 ft. thick). Loose sand below.

B. H. 22 (11° 33′ 40″ : 79° 30′ 30″).—Half a mile N. of Sanarpalayam at the N.W. end of tank. Surface level 153·3 ft. Total depth 270 ft. Lignite from 253 to 269 ft. (16 ft. thick). Sand below.

B. H. 23 (11° 33′ 50″ : 79° 31′ 40″).—Just S. of the eastern end of Mulakkuppam. Surface level 150 ft. Total depth 308 ft. Sand with lignite from 299 to 306 ft. (7 ft.).

B. H. 24 (11° 35′ 10″ : 79° 32′ 22″).—Two furlongs N.E. of Vanadarayapuram. Surface level 137·6 ft. Total depth 267 ft. Lignite from 253 to 264 ft. (11 ft. thick). Carbonaceous clay from 264 to 266 ft. Sand below.

B. H. 25 (11° 35′ 30″ : 79° 34′ 5″).—Western end of tank north of Kovilkuppam. Surface level 125 ft. Total depth 302 ft. Carbonaceous shale from 295 to 296 ft. No lignite.

B. H. 26 (11° 33′ 45″ : 79° 35′ 30″).—Just N.W. of Kurinjipadikuppam. Surface level 77·5 ft. Total depth 141 ft. No lignite.

B. H. 26A (11° 34′ 20″ : 79° 34′ 30″).—One furlong W.N.W. of Ellayappanpatti. Surface level 88·7 ft. Total depth 319 ft. No lignite.

B. H. 28 (11° 33′ 0″ : 79° 32′).—2 furlongs N.E. of Vilankani near Vadalur. Surface level 153 ft. Total depth 339 ft. No lignite.

B. H. 28 (11° 33′ 0″ : 79° 32′).—2 furlongs N.E. of Vilankani near mile 23¼ on Cuddalore-Vriddhachalam road. Surface level 94 ft. Total depth 302 ft. No lignite. Artesian water at 144 ft.

B. H. (A) (11° 29′ 30″ : 79° 23′ 50″).—Close to mile 5-3 furlongs on Vriddhachalam-Chidambaram road. Surface level 97·2 ft. Total depth 205 ft. No lignite. Artesian water at 194 ft.

B. H. (B) (11° 29′ 50″ : 79° 23′ 0″).—Near mile 4-3 furlongs on Vriddhachalam-Chidambaram road. Surface level 99·2 ft. Total depth 107 ft. No lignite.

B. H. (C) (11° 28′ 35″ : 79° 25′ 40″).—Near mile 7/4 on Vriddhachalam-Chidambaram road. Surface level 77·9 ft. Total depth 132 ft. No lignite. Artesian water at 70 ft. and 122 ft.

B. H. (D) (11° 28′ 25″ : 79° 26′ 45″).—Near mile 8/6 on Vriddhachalam-Chidambaram road. Surface level 70 ft. Total depth 154 ft. No lignite.

The data on the bore-holes are brought together in the accompanying table.

Bore hole No.	—	Surface level of site. Feet.	Depth to top of seam. Feet.	R.L. of top of seam. Feet.	Thickness of seam. Feet.	Depth to artesian stratum. Feet.
1	Gangaikondan . .	130·3	232	—101·7	51·5	294
2	Vadakkuvallur . .	120·7	149	—28·3	22	110 & 149
3	Gangaikondan . .	95·4	167	—71·7	34	230
4	N of Neyveli Rly. Stn. .	122·5	171	—48·5	22	195
5	Mile 28/7 Cud-Vri road .	90·3	—	—	—	121
6	Mile 30/3 Cud-Vri road .	116·4	—	—	—	91,132
7	N of Uttangal-Mangalram Rly. Station.	141·8	—	—	—	—
8	Mile 31/7 Cud-Vri Road .	130·8	—	—	—	—
9	W of Toppulikuppam .	152	—	—	—	—
10	Melkuppan . . .	197	—	—	—	—
11	N of Toppulikuppam .	146·9	157	—10·1	34	—
12	W of Kuravankuppam .	158	154·5	+3·8	33	—
13	S of Alandarkollai .	188·2	—	—	—	...
14	N of Kuravankuppam .	184·2	187	—2·8	13	—
15	S of Payirveli . .	201·5	179	+92·5	1	(Sandy lignite)
16	Permattur . . .	211·3	—	—	—	—
17	Vadakkutteruvu . .	162·6	185	—22·4	25	—
18	Veludaiyonpattu . .	151·1	185	—33·9	21	—
19	Mile 121, Vadalur-Panruti Road.	160·2	289	—129	4	—
20	Mile 122/2 Vadalur-Panruti Road.	103·3	241	—137·7	3	241
21	Terkukuppam . .	136	191	—55	15	—
22	Sanarpalayam . .	153·3	253	—99·7	16	—
23	Mulakkuppam . .	150	299	—149	7	—
24	Vanadarayapuram .	137·6	253·5	—116	10·5	—
25	Kovilkuppam . .	125	—	—	—	(Carb. sh. at 295)
26	Kurinjipadikuppam .	77·4	—	—	—	—
26A	Ellayapyanpatti . .	88·7	—	—	—	—
27	Kadukollai . . .	153·1	—	—	—	—
28	Vilankeni . . .	94	—	—	—	144

The lignite bed is noticed to thin down in the north of the area investigated. There are indications, in the older bore-hole records, of the existence of lignite in Aziznagar, Neyveli and Uyyakondaravi areas, since two bore-holes in the latter two villages showed lignite at depths of 260 ft. and 324 ft. respectively, the thickness of the seam being surmised as 50 and 81 feet respectively.

The available data point to the fact that the bed is of varying thickness, but generally showing a tendency to thicken towards the dip, which is roughly 1 in 100 in an E.S.E. direction.

The total area proved to contain lignite is of the order of 16 to 20 sq. miles. Assuming an average thickness of 20 ft. (and 1 million tons per square mile per foot thickness) the total reserves would be between 320 and 400 million tons.

Numerous analyses were done of the core samples obtained during the progress of investigation. The range of the constituents is :—

Moisture	11-16 per cent.
Volatile matter . . .	40-53 per cent.
Fixed carbon . . .	30-38 per cent.
Ash	3-6 per cent.
Phosporus	traces.
Sulphur	0·5 to 1·5 per cent. (mostly less than 1).
Calorific value . . .	9,100-9,900 B.T.U.

The analyses show that the quality is very good.

Since the minimum depth from the surface to the lignite bed is 150 ft. and since a part of the area is underlain by an artesian basin (the strata themselves being sandstones containing much water) there are some difficult problems to be overcome in successfully working the deposits. These will, it is hoped, be solved by experienced mining engineers who will have to draw up plans for mining the deposits.

It has already been stated that lignite was met with in three bore-holes put down near Bahur, a few miles north of Cuddalore, in the Pondicherry territory. Those bore-holes as well as the present investigation in the Neyveli area point to the probability of there being similar lignite deposits in the Tertiary strata which cover large areas along the coast from the Ramnad to the East Godavari district. A scrutiny of the logs of the numerous bore-holes sunk by the Industries Department and private citizens in these areas might possibly give a clue to the likely areas, though the bore-hole records of the Industries Department have proved to be the despair of geologists owing to unreliable descriptions given by the boring mistries. The Tertiary deposits in Malabar and Kanara also contain

lignite in places and fuller investigation is likely to bring to light workable seams present in them.

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CHAPTER XXVIII

LIMESTONE AND DOLOMITE

Limestone and dolomite are essentially made up of the carbonates of lime and magnesia (calcite and dolomite). When pure, limestone contains 56·0 per cent. CaO and 44·0 per cent. CO_2 while dolomite contains 30·4 per cent. CaO, 21·7 per cent. MgO and the rest CO_2. In nature, however, these materials always contain various impurities such as silica, alumina, iron, sulphur, etc., which may be present in the form of sand, clay, ferruginous matter, pyrite and so on. According to the dominant impurities, these are termed siliceous, argillaceous, ferruginous, etc., limestones.

Limestone and dolomite are of sedimentary origin and are laid down as beds. Sometimes, the limestones submerged under the sea during subsequent geological times may change their composition and be partially converted into dolomitic (magnesian) or phosphatic limestones. Ancient limestones formed in pre-Cambrian times and those subjected to intense metamorphic changes are gnerally seen to have acquired a crystalline structure. The impurities in them form new minerals most of which are calc-silicates (pyroxenes, amphiboles, scapolite, epidote, zoisite, garnet, chondrodite, etc.), but they may also contain hematite, pyrite, apatite, corundum and other minerals. These metamorphosed rocks are called crystalline limestone (or dolomites) if composed dominantly of calcite or dolomite; calciphyres if they contain less of silicates than carbonates; and calc-gneisses or calc-granulites if they are made up almost entirely of silicates.

Kankar (a Hindi word applied to nodular lumps of limestone in the soil) forms in the soil as a result of aggregation of the lime. It is usually found at a depth of 2 to 5 ft. from the surface, often as a more or less continuous bed-like formation, mixed with the soil. In the black soil areas, kankar is frequently mixed with grains and crystals of gypsum.

Uses

Limestone and dolomite are used extensively as building stones. Their durability, appearance and ease of working are primary considerations. Those of good colour and uniform grain may be used as ornamental stones. The metamorphosed varieties are usually referred to as marbles. Medium to fine grained varieties of uniform white and grey colours are preferred for statuary while very fine-grained and exceedingly uniform sedimentary limestones are made use of as lithographic stones.

Both limestone and dolomite are used as metallurgical fluxes. They are added to the furnace charge not only to lower the melting point but also for forming slags with the impurities present in the

ore. The iron and steel industries consume large quantities of limestone and dolomite. Dolomite has been used dead-burnt as a refractory, in recent years, in U.S.A. and Canada.

For the manufacture of cement, clayey impurities are not objectionable but iron should be low, magnesia should not exceed 3 per cent., silica usually kept below 6 per cent. unless it is part of the clayey impurities.

Limestone and lime are used as a soil conditioner in agriculture; in glass, sugar, tannery, water purification, and certain chemical industries; as a filler in paints, glues and other materials. As an intermediary in the process lime is used in the manufacture of paper, sugar, tanning of hides, preparation of fatty acids and glycerin from fats, manufacture of chromates, di-chromates and chlorates, in the preparation of certain organic compounds such as acetic acid, citric acid, lactic acid, etc.

For certain industries such as glass, enamels and glazes, caustic soda and soda ash, calcium carbide, calcium cyanamide, bleaching powder and hypochlorite, the limestone must be of high purity. Very little iron is permissible in these cases, but a little silica and alumina may be allowed, if these are less than 2 per cent.

Limestone is converted into quicklime by calcination in a shaft kiln or in a rotary furnace. Quicklime is essentially calcium oxide, together with the non-volatile impurities present in the original limestone. Much progress has been made in Europe and America in the manufacture of lime in properly designed kilns but the methods used in India are mostly primitive and wasteful of heat.

High-calcium limestone is dissociated at about 1,650° F. (900° C.) whereas magnesite is dissociated at about 1,000° F. (530° C.). The dissociation of dolomite takes place between 1,000° F. and 1,380° F. The temperature of calcination and time taken have an effect on the product obtained—its particle size and hence the plasticity. The finer the particle size the greater the reactivity of lime and the longer the time of settling. The rate of slaking is also important. When slaking, quicklime absorbs water and produces slaked lime, $Ca(OH)_2$. This is a white powder with an apparent density of 0·9; the particle size being 0·01 mm. or less.

Lime is used in mortar, stucco, for whitewash and as a base coat for plasters. High-lime mortars are plastic and have a good binding and water-retaining capacity. In India a solution of sugar or molasses (gur) has been mixed with mortar from time immemorial to produce a very strong mortar particularly for arched brick and stone roofs. For whitewash, it is advantageous to add a solution of casein, trisodium phosphate and a little formaldehyde to the lime before application. Pigments such as red or yellow ochre, red oxide,

ultramarine, cobalt blue, chromium compounds, etc., are added to whitewash and plaster before application in order to give a pleasing colour to the surface to which they are applied.

Distribution

VIZAGAPATAM AND JEYPORE

Limestones of grey, green and black colours occur on the low saddle above the village of Nilgalgunta, having a thickness of about 90 ft.

Six miles to N.N.E. of the above, near the village of Borra (which is close to Anantagiri on the road from Vizianagram to Jeypore) there is a large outcrop of crystalline limestone through which a stream passes to join the Peddagunda river. There is a large natural cave in this limestone with a lofty dome-like roof and showing numerous stalactites and stalagmites. It connects with a smaller cave beyond. This limestone band is perhaps 500 ft. thick, massive, white to pale grey, granular and compact. It is partly a high calcium limestone and partly dolomite. Some beds are pure white and of uniform medium to fine grain, suitable for use as an ornamental stone and for monuments and statues. Dr. King compares this to good Carrara (Italian) marble (*Rec. Geol. Surv. Ind.*, XIX, pp. 143-156, 1886).

Purple siliceous dolomite with N.E. strike is exposed at Bunsuli. Near Kondajori (18° 58′ : 82° 16′) some 5 or 6 miles to the south, pink and white mottled dolomite is seen which should make excellent decorative stone. Further south, at Araguda (W. of Ramagiri) grey argillaceous limestones are cut through by the Kolab river which cascades over them. Similar rocks are reported to occur also at Gupteswar, a couple of miles to the north. (T. L. Walker: in General Report of the Geological Survey of India for 1899-1900).

EAST AND WEST GODAVARI

Cherla.—An exposure of grey fine-grained limestone (Cuddapah or Archaean) occurs 1½ miles east of Cherla (18° 4′ 30″ : 80° 49′ 30″) and just north of the hamlet of Bhumanlanka. It is 3 furlongs long and 20 ft. wide and shows a general E.S.E. dip. It is said that lime made from this was used for the construction of the *anicut* at Dummagudem (a few miles above Bhadrachalam) on the Godavari over 100 years ago.

Another exposure is seen 2½ furlongs S.S.E. of Bhumanlanka, on the left bank of the Talperu. It is 600 ft. long and 75 ft. wide. These two deposits are estimated to contain 150,000 tons and 35,000 tons respectively, within a depth of 10 ft. from the surface. It is probable that the two may be parts of a single folded bed.

—		CaO	MgO	R_2O_3	Insol.
First deposit :					
Range of amples	Max.	51·42	2·70	3·00	32·24
	Min.	30·54	0·43	0·50	3·70
Second deposit :					
(1 sample only)		37·20	0·87	3·30	24·96

The few analyses available show that the material is a high calcium limestone with a maximum of 2·70 magnesia, but silica has a larger range. The limestone should be suitable for lime and cement manufacture.

Duddukuru-Rajahmundry.—A sinuous band of inter-trappean limestone is seen in the Kovvur taluk extending over a length of 4 miles or more from the Linga konda near Pangadi (17° 1′ : 81° 39′) on the east to near Devarapalle (17° 2′ : 81° 35′) on the west, a short distance south of the trunk road joining Ellore and Kovvur in West Godavari. It crops out from amidst the traps on the slopes of low hillocks. The band has a maximum thickness of about 25 ft. but thins down to 3 or 4 ft. at and near the ends. It generally consists of a bed of hard compact limestone making up the lower half, while the upper half consists of shaly, chalky and nodular material. The layers are not very regular when followed along the strike or dip (southward at 4°-6°). The hard limestone in the lower half is generally magnesian (10-15 per cent. MgO) whereas most of the upper portion is low in magnesia.

Taking a length of two miles (the middle portion of the band) and a width of 250 ft. (in the dip direction) as the workable portion, the total quantity available would be about 3·4 million tons. To work for a longer distance along the dip would necessitate the adoption of underground mining methods. As much of the limestone is too high in magnesia, it is estimated that the deposit would yield only a little over 1½ million tons suitable for cement manufacture. This is too small to support a moderate sized cement plant for any length of time.

Another band of the same nature, and in the same stratigraphic position (inter-trappean) occurs to the east of the Godavari and a little to north of Rajahmundry, stretching from Kateru (17° 2′ : 81° 47′) in a north-eastern direction to beyond Kuntamuru (17° 2′ 30″ : 81° 48′) for a length of about 2 miles. This band is only about 5 ft. thick on an average and has already been worked for a width of 150-200 ft. and used for lime burning. The overburden at present

is 15-20 ft. trap. Though the limestone is of good quality for cement making it is doubtful if it can be mined economically. Some typical analyses are given below :—

—	SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO
Kovvur area :					
Hard limestone	1·84	1·08	1·62	34·01	16·62
Shaly limestone	20·02	3·48	4·12	34·95	2·21
Nadular limestone	11·56	2·57	3·63	41·60	1·41
Rajahmundry area :	2·96	0·12	1·58	51·44	1·23

(Analyses by the Geological Survey of India, Calcutta.)

KISTNA AND GUNTUR

The rocky banks of the Kistna south of the village of Bellagarige are composed of compact white and greyish limestones. They become interlaminated with argillaceous bands when traced towards Cautranepali.

Limestones of the Narji stage are developed on both sides of the Kistna river in the Palnad tract of Guntur and in the Jaggayapeta and Mutyala tract of Kistna (*Mem. Geol. Surv. Ind.*, VIII, Appendix, pp. 293-313). They include light to dark grey flags and limestones of various colours and of good quality suitable for building and decoration. Fine grey and variegated limestones occur near Jaggayapeta, resting on quartzites. A large spread of compact grey and white limestones is seen near Mutyala dipping east to 10°-20°. The thickness in some places in 80-100 ft., but it is also thicker due to repetition by folding.

On the right bank, limestones are exposed near Pulichinta where they are greenish in colour. They are continued towards Cuchillabode where they become flaggy. Lithographic limestone occurs near Kondapilli (16° 37′ : 80° 33′) and Betavole (16° 53′ 30″ : 80° 6′) near Jaggayapeta and also near Chintapalle (16° 42′ : 80° 9′) on the Kistna river.

Limestones are being quarried near Piduguralla (on the Guntur-Macherla branch line) for use in making cement at the factories at Bezwada. At Durgi, white, yellow, pink and light green limestones are exposed while banded varieties are seen on either side of the railway track for a distance of more than 3 miles near Nadikudi. Very fine marbles of chocolate, pink, sea-green, white, grey and black colours have been quarried from near Rentichintala and excellent examples of these have been used in the palatial residence

of Sri Chundur Venkata Reddy at Bezwada. Other localities at which limestones and marbles occur in this region are Uddalur, Konanki, Dachepalle, Kesanapalle, Sitaramapuram, etc., all in the Palnad tract. The Kistna river between Amaravati and Warapilli flows largely through limestones. Good lithographic limestone is known to occur near Dachepalle. As this region has not been mapped in detail, the information at present available is sketchy and incomplete.

Kankar is widely distributed in Guntur, particularly in the black cotton soil tracts. W.S.W. of Mangalagiri (16° 25′ 45″ : 80° 34′) there is a 3 to 6 ft. layer which is quarried by the Kistna Cement Works for use in cement making. Near Chebrolu (16° 12′ : 80° 2′), Pratipadu (16° 16′ : 80° 20′), Budavada (15° 51′ : 80° 9′), Nagandla, and Venkayalapadu (15° 55′ : 80° 13′) kankar is quarried for use as a building stone and for making lime. It is also won at or near Guntur, Lalupuram (18° 15′ 30″ : 80° 25′), Peddakakani (16° 20′ 30″ : 80° 29′ 30″), Nekallu (16° 29′ 30″ : 80° 26′ 30″), Sripuram (16° 24′ : 80° 18′), Peddakkupadu (16° 28′ : 80° 15′ 30″) and other places. A large spread of it occurs at the north-eastern end of Kottappa konda and at Yellamanda, 4 miles south of Narasaraopet.

NELLORE

Limestone.—A small patch of crystalline limestone is seen one furlong east of Korivivandlapalle (15° 26′ : 79° 31′) but its full extent is not known. In places it is light green in colour.

Foote has mentioned (*Mem. Geol. Surv. Ind.*, XVI, Pt. 1, p. 23) a few occurrences in this district.

South-west of Chundi, the western slopes of a ridge shows a 5-foot thick band of saccharoidal limestone. It is several yards long. Fragments of pale-grey and pink limestone have been noticed on the high ground 3 miles N.E. of Pedda Alavalapadu but the bed is obscured by soil cover. Nearly white to pale grey limestone is exposed east of Pedda Arikatla 8 miles N. by E. of Kanigiri, but the outcrop is obscured by soil. Similar limestone is noticed S.W. and east of Irslagudem, about 2 miles W. by N. of the above. Impure limestone occurs at Punnugodu, 5 miles E. by N. of Kanigiri, the curved outcrop of which is 200 yards long and 8-10 ft. thick. It is injected by pegmatite veins.

A bed of crystalline limestone is seen to cut across the Kavali-Udayagiri road at mile 35, having a width of 30 ft. Its length is 300 yards or more.

Kankar is fairly widespread in this district and is worked at Darsi (15° 46′ 36″ : 79° 41′), Battuvaripalli (15° 38′ : 79° 32′ 30″), Nandipalem (15° 35′ 30″ : 79° 35′), Talamella (15° 35′ 30″ : 79° 43′ 30″), Edavalli (15° 28′ : 79° 32′ 30″), etc.

According to Foote (*Mem. Geol. Surv. Ind.*, XVI, Pt. 1, pp. 99-100) a bed of massive kankar is found about 2 miles W by N of Pamur near the embankment of the Dupuguntla tank. A similar formation is seen in the waste channel of the Kanigiri tank, extending westwards. Another important occurrence is seen along the brow of the high ground south of the Paleru valley 3 miles north of Kandukur. It forms a large sheet near Konda Kandukur. A dense and fairly massive deposit of kankar is seen also at Kovur, resting on the Upper Gondwanas.

Tufaceous material forms a thin bed in the basin of the Upputeru river. It is quarried and dressed into blocks for building purposes at Janakammapeta (15° 1′: 79° 51′), Peddapavani (15° 0′ 30″: 79° 49′), Mutyalapad (14° 59′ 30″: 79° 48′ 30″), Kommi (14° 58′: 79° 46′) and Adimurtipuram (14° 58′: 79° 41′).

Marine shells.—Beds of marine shells occur along the borders of the Pulicat Lake near Mijuru (11° 46′: 80° 5′), Atakanitippa (13° 43′: 80° 7′ 30″), Venadu (13° 38′: 80° 7′ 30″), Tada (13° 35′ 30″: 80° 2′), Irkam (13° 34′: 80° 9′) and Sulurpeta (13° 42′: 80° 1′). These beds vary from 12 to 18 inches in thickness and occur within 4 ft. of the surface. Though the distribution is irregular, it may be stated that every sq. mile of shell bearing area contains about 1 million tons of shells. The area occupied by the beds is not known, but it may be about 2 sq. miles.

CUDDAPAH AND KURNOOL

The chief limestone formations in these two districts are the Vempalle dolomitic limestones of the Cuddapah system and the Narji limestones and calcareous flags of the Jammalamadugu stage of the Kurnool system. Both these formations are well developed in this region.

The Vempalle limestone formation extends from near Cuddapah through Vempalle, Pulivendla, Parnapalle, Beduduru Hill, Rayalacheruvu to near Betamcheria and further north. Its outcrop varies in width from 1 to 4 miles in different places. It is generally dolomitic and silliceous and often contains bands and lumps of cherty silica. The colour varies from white to cream, grey and pink. It becomes serpentinous in contact with intrusive trap in a few places—*e.g.*, near Pulivendla. Occasionally it has been changed to steatite (*e.g.*, near Mutssukota). Most of the barytes deposits occur in this formation or in associated traps and shales. It is only occasionally that it contains veins of calcite or thin bands of high-calcium limestone, *e.g.*, near Tabjula (14° 54′: 77° 49′ 30″) and Chandrapalle (15° 12′ 30″: 77° 49′).

The range in composition and average of 10 analyses of these limestones are given below:

——	Average per cent.	Range per cent.
SiO_2	9·70	0·54—37·10
Al_2O_3, Fe_2O_3	2·15	0·30— 4·20
CaO	31·10	19·38—49·25
MgO	15·80	3·53—21·30

The Narji limestone is of two types. The lower part of the formation is a massive limestone, often of pleasing colours, uniform grain, compact and suitable for use as a building and ornamental stone and for cement manufacture and chemical purposes. The upper part is usually an argillaceous flaggy limestone yielding slabs of various sizes, of light to dark grey colours. Slabs from half an inch to 4 or 5 inches thick, up to 6 or 8 ft. long and 2 to 3 ft. wide can be obtained. They are famous all over this Province as 'Cuddapah slabs' and are widely used for paving floors and roofs, as table-tops, door and window sills, for fences, etc. A large number of people are engaged in quarrying these stones which are used all over this Province and in Mysore and parts of Bombay Province. They are quarried near Narji, Yerraguntla, Chagalmarri and Jammalmadugu in the Cuddapah district; near Kurnool, Betamcherla, Kalugotla and other places in the Kurnool district and also in the Paland tract in Guntur and Mutyala in Kistna. An average analysis of the flaggy limestone from near Kurnool shows 27·3 per cent. silica, 7·9 per cent iron and alumina, 33·1 per cent. lime and 1·5 per cent. magnesia.

Similar flags also occur in the Kundair stage of the Kurnool formation and are worked in several places.

Large spreads of the massive limestone are also seen in these district—*e.g.*, south-east of Kurnool town, near Nandyal, Paniam, Betamcherla and other places. These are high calcium limestones generally suitable for cement manufacture and in some cases for use in the chemical industry.

Lithographic limestone.—Some places in the Tungabhadra valley in Kurnool and in the Nandyal taluk yield good stones suitable for lithography.

Chalk and chalky clay.—Thin beds of fine powdery chalk occur intercalated with Vempalle dolomite beds in quarries half a mile N.N.E. of Chinna Malkapuram (15° 22′: 77° 59′). The quantity available seems to be very limited.

Just S. and S.E. of the village of Palkur (15° 25′:78° 15′) 7 miles N.N.E. of Banganapalle, are several exposures of soft chalk formerly described as white calcareous clay. It occurs amidst the Jammalamadugu flags and occupies an area of 5 by 3 furlongs to a depth of 10 or 12 ft. below the mantle of soil. A minimum of *2 million tons* of chalk is estimated in this deposit, with double this quantity as probable reserves.

Near Nandavaram (15° 22′:78° 17′), which is 10 miles S.S.W. of Paniem Railway Station, there are 3 or 4 exposures of the same material. The first, 2 furlongs N.N.W. of the village measures 350 yds. by 200 yds. and shows a 5-foot layer of chalk capped by a thin bed of calcareous tufa. The second exposure, located 1 furlong north of the village, occupies an area 450 ft.×120 ft. and contains a chalk bed of at least 4 ft. thickness. The third exposure, on the western outskirts of the village, is about 100 yds.×100 yds. in area and 3 ft. thick. The fourth, two furlongs N.W. of Nandavaram, is exposed in an area of 500 yds. by 300 yds. and is apparently more than 6 ft. thick. The deposits are all likely to be larger than they appear and the thickness should also be more since the above figures have been taken from shallow pits put down in them. The minimum quantities available in these deposits are:

Deposit 1	158,000 tons
Deposit 2	8,000 ,,
Deposit 3	27,000 ,,
Deposit 4	405,000 ,,
TOTAL . .	598,000 tons

The following analyses are of representative samples for the above deposits:

—	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
C. Malkapuram .	2·39	0·93	1·06	47·53	4·42
Palkur . . .	3·05	0·50		52·25	1·63
Nandavaram . .	2·77	0·91	0·79	52·08	0·48

Much the greater part of the material in the Palkur and Nandavaram deposits is soft white powdery chalk but it contains a small amount of small hard calcareous nodules and some gritty material which can easily be separated. The white chalk can be used as a filler.

Tufa.—There are also fairly extensive spreads of tufa about 6 furlongs N.N.W. of Nandavaram and 6 furlongs N.E. of Palkur.

Kankar and tufa.—Large quantities of kankar have been formed over the slates of the Markapur-Cumbum belt, especially near Markapur and Pedda Obanayanipalle. It is apparently argillaceous and may yield hydraulic lime on burning.

A large deposit of calcareous tufa occurs at Bugganipalle (15° 22′ 30″ : 77° 53′ 30″) near Dhone or Dronachallam. The material is apparently derived from the underlying Vempalle limestone. The deposit covers an area of 2 sq. furlongs and is 8-10 ft. thick. Another deposit is found near Periked about a mile to the west. It occupies an area of 3 furlongs by 1 furlong and has a thickness of 6 to 8 ft. This material is light grey or brownish. These deposits have supplied material for flux at the Iron Works at Bhadravati, Mysore, as much of it is of high quality with less than 4 per cent. impurities.

Kankar deposits are widespread in these district and are worked for local use at several places.

BELLARY

Limestone was noted only in four places in this district by Foote (*Mem. Geol. Surv. Ind.*, XXV, p. 88).

(*a*) On top of the ridge crossed by the road from Huvina Hadagalli to Magalam, about half a mile west of the Dharwarian exposure, a few thin bands are seen intercalated with schists.

(*b*) About 2½ miles south of the above and at the southern extremity of the ridge north of Haggarnur, there is a band of coarse limestone containing grains of quartz.

(*c*) Three miles E. 55° N. of Harappanahalli on the ridge west of Hambalgutta village, there is a 2-foot thick band.

(*d*) Near Tallur, 3½ miles S.W. of Tornagallu there is a small band obscured by soil.

None of these is of any size or importance. At several places in the district there are small deposits of kankar which can be exploited for local use.

ANANTAPUR

The Vempalle and Jammalamadugu limestones are found in this district and are worked in a few places in the Tadpatri and Gooty taluks.

A large stretch of tufaceous limestone is found on the hill side 3½ miles north of Kona Uppalapadu (15° 6′ : 77° 54′) just east of the gorge of a stream emerging from it. This is won and burnt into lime at Rayalacheruvu. It is of good quality.

Deposits of kankar are found N.W. of Daditola (14° 35′ 30″ : 77° 58′) and also east of Chilavaripalle (14° 37′ 30″ : 77° 54′) and at other places. They are worked for local use.

SOUTH ARCOT

The Cretaceous strata in Pondicherry and neighbouring parts of Tindivanam taluk, South Arcot, contain beds of shell-limestone and massive argillaceous limestone passing through Sedarampattu (11° 59′: 79° 45′), Tuttipattu and other villages east of Vanur, in a N.E.-S.W. direction. Though not of high quality, they may be useful for cement manufacture.

Limestone, much obscured by sandy soil, occurs also near Sendamangalam (11° 44′ 30″: 79° 23′) about 5 miles north-east of Ulundurpet Railway Station. The quality appears to be good, but little is known about the extent.

TANJORE

Fairly large patches of kankar and tufaceous limestone occur to the south of Alakkudi Railway Station (10° 47′: 79° 4′) and W.S.W. of Tanjore town in the villages of Tirumalaisamudram, Marudakkudi and Kalivirayanpettai. The thickness varies from 3 to 10 ft. The material is high in lime and low in magnesia and is at present being used for lime burning.

Analyses

—	1	2	3	4
SiO_2	6·62	3·19	5·99	3·96
R_2O_3	6·52	1·16	2·30	2·73
CaO	48·43	52·72	47·96	51·36
MgO	0·72	0·09	2·17	0·18
Ign. loss	40·16	42·60	41·00	41·00

The quantity available in these deposits is estimated at over half a million tons. The kankar appears to be derived from the underlying calcareous sandstones of Cretaceous age.

TRICHINOPOLY

Massive limestone.—The Cretaceous rocks occurring in the Lalgudi and Perambalur taluks contain limestones some of which are now being used by the Cement works at Dalmiapuram near Pullambadi on the S. I. Ry. The same limestone is also quarried at Karai (11° 8′: 78° 53′) and Kalpadi (11° 11′ 30″: 78° 55′ 30″) for local use as a building stone. The fresh stone is blue grey but on exposure becomes yellow. It is low in magnesia but contains much silica and a lower amount of iron and alumina.

Shell limestone.—The shell limestone occurring at Garudamangalam (11° 5′ : 78° 55′), Anaipadi (11° 6′ : 78° 56′ and Kunnam (11° 14′ : 79° 1′) in this area, is a handsome ornamental stone when polished but is now used locally merely for making mortars, grindstones and water-troughs.

Calcareous nodules.—Nodules of limestone, similar in appearance to the phosphatic nodules, occur near Maruvattur (11° 12′ : 78° 58′) where the quantity available may run into a few thousand tons. An analysis of a typical sample showed 42·8 per cent. lime, 12·1 per cent. silica, 5·5 per cent. alumina, 1·5 per cent. iron oxide, 0·6 per cent. magnesia and 0·2 per cent. phosphoric oxide.

Chalk.—Nodules of chalky limestone and chalky clay occur in veins traversing the Uttattur clay beds near Karai (11° 8′ : 78° 53′), Terani (11° 6′ : 78° 52′), Varaguppadi (11° 9′ : 78° 54′) and Neykulam (11° 3′ : 78° 50′ 30″), in an area of 5 or 6 sq. miles. At a rough estimate about 1½ million tons of this material should be available within a depth of 10 ft., but much of it is soft and cannot be easily separated from the clay which flanks the thin veins. The central portions of the veins contain moderately hard nodules which are scooped out, burnt and used locally for whitewashing. It yields excellent 'fat' lime and should be useful for making whiting on a small scale as several thousand tons may be available within a shallow depth. An analysis of the material shows 54·6 per cent. lime, 0·62 per cent. magnesia, 1·12 per cent. silica and 0·5 per cent. total iron and alumina.

Fibrous limestone.—Over almost the whole area containing gypsum, the Uttattur strata show veins of fibrous calcium carbonate with cross-fibre structure (fibres with their length perpendicular to the veins). Good exposures are seen near Ayinapuram (11° 6′ 30″ : 78° 56′). The quantity available in an area of 10 sq. miles within a depth of 10 ft. from the surface is estimated at 76,000 tons. An analysis of the material shows 51·87 per cent. lime, 1·09 per cent magnesia and less than 3 per cent. silica, iron and alumina together.

Crystalline limestone.—There are 3 major bands of crystalline limestone in the Kadavur Zamindari in the Kulittalai taluk:

(*a*) *Tarakkampatti band.*—This is seen 6 furlongs south of Tarakkampatti (10° 42′ 30″ : 78° 14′ 30″) dipping at 70° to the S.S.E. The total length is half a mile, part being calciphyric. Just west of the Tarakkampatti-Palaividudi road where the band is 350 yds. wide, the southern part shows good white to pale grey limestone the rest being an impure talc-gneiss with intercalations of mica-gneiss and pegmatite This band is estimated to contain 92,000 tons of good limestone in a depth of 10 ft.

(*b*) *Allinagaram-Devarmalai band.*—This is about 10 miles long and 300-400 yds. wide, but continues beyond Allinagaram (10° 45′ 30″ :

78° 18′) eastwards into Kulittalai taluk and beyond Devarmalai (10° 44·: 78° 10′) westward into the Madura district. The dip is S.S.E. 60°-75°. The band becomes wider beyond Devarmalai. Some bands in this, each 25-30 ft. are of good limestone, the rest being calciphyre and calc-gneiss. This is estimated to contain over 400,000 tons of high calcium limestone (to a depth of 10 ft.) in the portion exposed in Kadavur Zamindari.

(c) *Kiranur band.*—A band 3 miles long and up to 400 yds. broad is seen just south of Kiranur (10° 47′: 78° 17′). It contains both good limestone and calciphyre. At two places in this band cordierite and corundum are developed. The good limestone in this band is estimated at 52,000 tons within a depth of 10 ft.

Amongst the good limestones in these bands there is some dolomitic material but more than half may be said to be high-calcium limestone. The Devaramalai band has not been fully examined, so that additional quantities of good material may be confidently expected to be available.

SALEM

Several bands of crystalline limestones have, in recent years, been mapped and investigated in the Tiruchengodu and Namakkal taluks of this district by Mr. N. K. N. Aiyengar and the writer. A short summary of the results are given below, but the reader may refer to the two publications on these (given under 'References') for further details.

1. *Ardhanaripalaiyam* (11° 11′: 78° 0′).—E.S.E. of this village, limestone is exposed in a stream for 250 ft., with a width of 2 ft. striking W.N.W.-E.S.E. Another band, in a field north-east of the village, continues to mile 9/1 on Paramati-Namakkal Road, and has a width of 100 to 120 ft.
2. *Nayakkanpalaiyam* (11° 14′ 30″: 78° 0′ 20″).—A band 2 to 3 ft. wide and 250 ft. long runs through the village in a N.W.-S.E. direction. Two other parallel bands of similar thickness are seen north-east of the village, each having a length of 70-80 ft.
3. *Kuttikkaranpalaiyam* (11° 15′: 78° 1′).—Two short bands of 2 ft. thickness are seen S.E. of the village and they apparently continue into two other bands seen further south. The total length is about 200 ft.
4. *Kuttamparai* (11° 8′: 78° 6′).—About 2½ furlongs south of the village is an 8-foot thick band exposed for 70 ft. and probably continuing for another 200 ft. It contains some calciphyre also.

5. *Pirandagam* (11° 15′: 78° 2′).—W.N.W. of this village are two short bands 5 ft. and 8 ft. thick respectively but their continuations are impure limestones.
6. *Nadandai* (11° 12′: 77° 58′ 30″).—Half a mile south-east of this village along the path leading to Puliyampatti, is a band traceable for 600 ft. (N.-S.) having a thickness of 90 ft. of good limestone, and an equal width or more of calciphyre.
7. Some exposures of good limestone are seen south of Nadandai in some wells.
8. *Ramanathapuram* (11° 11′ 30″: 77° 58′ 30″).—An exposure of pink limestone, 100 ft. long and 5-6 ft. wide is seen one furlong west of this village. It is associated with some calciphyre.
9. *Vadagarai Attur* (11° 8′: 77° 54′).—Limestone is seen one mile E.S.E. of this village, having a length of 300 ft. (E.-W.). Some of this is good and the major part calciphyric.
10. *Tiruchengodu-Namakkal road.*—At mile 7/6 on this road a N.N.E.-S.S.W. band is seen. It is half a mile long and 30-100 ft. wide but partly obscured by soil. This continues into the adjoining map sheet.
11. *Sattinayakanpalaiyam* (11° 22′ 30″: 77° 56′).—A band of coarse calc-spar is seen near this village. It is 30 ft. long and 2 ft. thick and may be larger.
12. *Dasinayakanpalaiyam* (11° 26′ 30″: 77° 53′).—Three small bands are seen south of this village, the westernmost being near milestone 3 on Sankaridrug-Tiruchengodu road. Each of them is 40-50 ft. long and 10 ft. thick and of good material.
13. *Vakkalippatti* (11° 25′: 77° 55′).—Good white granular limestone crosses the Kolikkalnattam-Tiruchengodu cart track at this village. It is 2 furlongs long (N.W.-S.E.) and 15 ft. wide.
14. *Kolikkalnattam* (11° 26′ 30″: 77° 55′).—A thick N.-S. band is seen 6 furlongs S.S.E. of this village on high ground. To the north it continues into the Iveli-Mavelipalaiyam band (*see* below). The limestone here is 600 yards long and disappears under soil at both ends. It is 60-100 ft. wide. It reappears just south of the village where it is 150 ft. long and 10 ft. wide.
15. *Chettippatti* (11° 27′: 77° 55′).—A band seen in this village is 150 ft. long and 30 ft. wide.
16. A group of parallel bands extends from near Kolikkalnattam in the south, through Annadanappatti, Mavelipalaiyam (11° 29′: 77° 54′) and Iveli, to Devakkavundanur and

Manjakalpatti in the north. It crosses the Salem-Sankaridrug Road at mile 251/1, about 2 miles east of Sankaridrug. This band has a W.N.W.-E.S.E. strike to the north of the road and gradually veers round to N.N.W.-S.S.E. strike south of the road. It contains mostly calciphyre in the part north of the road. In the southern stretch, the western half contains several good bands of high-calcium and dolomitic limestone, the eastern half being largely calciphyre partly calc-gneiss. The total length of the band is about 6 miles and the width 500-700 yards, with some bands of gneiss and pegmatite intercalated with them. A part of this deposit is being worked by the Mettur Chemical Corp. near Iveli village for use in the manufacture of bleaching powder.

17. *Hill* ·*1492* (11° 27′ 30″ : 77° 50′ 30″).—Two miles west of Sankaridrug, a band traverses this hill in a N.W.-S.E. direction. Much of it is calciphyric but there is also some high grade limestone. It is likely that this band continues under the soil to the S.E. in the plains towards the Sankaridrug-Bhavani Road. An exposure is seen cutting the road at mile 255/6 for a distance of 100 yds. with a width of 15 ft. and this may be the same band.

18. *Kolenjipalayam* (11° 27′ : 77° 51′).—Two furlongs south of this village is an outcrop 100 yds. long and 15 ft. wide. It is probably much larger.

19. *Sanniyasippatti* (11° 27′ : 77° 50′).—Half a mile south of this village is an exposure of good limestone measuring 100 yds. by 5 ft. but it is much obscured by soil and may be much larger.

20. *Puduppalaiyam* (11° 25′ : 77° 47′ 30″).—A band is found cutting across the Sankari-Pallipalaiyam Road at mile 5/6 in a N.W.-S.E. direction. The length is not less than 400 yds. and the average thickness 20 ft.

21. *Puduppalaiyam-Pulappalaiyam* (11° 27′ : 77° 47′ 30″).—Some thick parallel bands of good limestone are found running in a N.-S. direction between these two villages. The total observed length is over 4,100 ft., but may be actually more. The aggregate thickness is more than 250 ft. the good material perhaps occupying 60-100 ft. of this thickness.

22. *Malappalaiyam* (11° 27′ : 77° 47′ 30″).—At mile 259/4 on the Sankaridrug-Bhavani Road, a large exposure of limestone is seen north of the road. The outcrop is 240 yds. long and 40 yds. wide.

23. *Mudalaimadayur* (11° 26′: 77° 48′).—There are 6 or 7 outcrops of limestone half a mile south of this village, but they are largely obscured by soil.

24. *Salaipalaiyam* (11° 20′:77° 56′).—Kattuppalaiyam (11° 19′ 30″: 77° 55′).—A thick composite band is seen half a mile N.W. of Gandhi Ashram near Puduppalaiyam (just N.W. of Kattuppalaiyam). It consists of some 10 individual bands varying in length up to 300 ft. and in width up to 50 ft. There is much good quality material here, including coarse and granular varieties.

25. *Olaippalaiyam* (11° 6′:78° 3′).—Half a mile north of this village are four W.N.W.-E.S.E. bands which can be traced from near the Pallappatti-Sircar Valavandi road to near Unjapalaiyam and the Namakkal-Paramati Road. From south to north, the bands are 10 ft., 5 ft. and 5 ft. wide respectively. All the bands are largely of calciphyre.

26. *Puduppalaiyam* (11° 8′ 30″:78° 6′ 40″).—White and pink limestone and calciphyre are seen to the west of this village. The band is 6 furlongs long and 300 ft. thick but includes some intercalations of biotite gneiss. It thins down towards the west.

27. *Pilikkilipalaiyam* (11° 8′ 40″:78° 4′).—East of this village is a prominent band of calciphyre 2 furlongs long and 70 ft. wide. Between this village and Sircar Valavandi (11° 7′ 20″:78° 3′) some thin bands are seen, while to the W.S.W. of the latter village there is a 70 ft. thick band traceable for 2 furlongs. Thin bands are seen near Vettuvampalaiyam (11° 6′:78° 5′ 20″). Just S.W. of Ganapatipalaiyam (11° 5′ 20″:78° 6′ 30″) there is a band over 60 ft. long and 6 ft. wide, and another smaller band. All these are largely of calciphyre.

28. *Toppur* (11° 6′:78° 4′).—Two furlongs S. of Toppur is a band half a mile long, cutting the Namakkal-Mohanur Road. South of this is another which is 300 yds. long. They are about 40-50 ft. thick each, and mainly calciphyric.

29. *Parali* (11° 7′:78° 11′ 30″).—Two furlongs S.S.W. of this village is a band of calciphyre 150 ft. long and 20 ft. thick.

30. *Nayakkanpalaiyam* (11° 0′ 30″:78° 4′ 30″).—A band runs in N.W.-S.E. direction through this village for over half a mile, with a width of 100-120 ft. including intercalations of gneissic rock. It is largely made up of calciphyre.

Estimates of quantity.—In making estimates only the visible good limestone bands have been taken into account, and those with appreciable amounts of silicates have been left out. They include both

limestone and dolomite, the former predominating. The depth assumed in each case is only 10 feet.

	Quantity tons.
1. Ardhanaripalaiyam	400
2. Nayakkanpalaiyam	1,200
3. Kuttikkaranpalaiyam	100
4. Kuttamparai	1,600
5. Pirandagam	200
6. Nadandai	33,300
8. Ramanathapuram	400
9. Vadagarai Attur	1,200
10. Tiruchengodu-Namakkal road	58,000
12. Dasmayakanpalaiyam	200
13. Vakkalippatti	13,800
14. Kolikkalnattam	60,000
15. Chettippatti	3,500
16. Iveli	75,000
16. Mavelipalaiyam and south	26,000
17. Hill (·1492)	10,400
18. Kolenjipalaiyam	1,100
19. Sanniyasipatti	7,000
20. Puduppalaiyam	23,100
21. Puduppalaiyam-Pulappalaiyam	175,700
22. Malappalaiyam	63,700
23. Mudalaimadaiyur	45,400
24. Salaipalaiyam-Kattupalaiyam	139,700
TOTAL	741,000

As remarked above, this estimate refers only to the best portions of the deposits and for a depth of only 10 ft. Several of them are likely to be more extensive than assumed above, since their full extent in area has not been investigated. In most cases they can be expected to continue to some depth, perhaps 100 ft. or more.

COIMBATORE

In the hills near Madukkarai (10° 54′: 76° 57′), about 7 miles south of Coimbatore, there are extensive beds of crystalline limestone of grey and pink colours, interbanded with gneissic rocks. They strike in a N.E.-S.W. direction and have a total length of nearly 7 miles. The width varies between 50 yds. and 450 yds. The material is

different in quality in different portions. The Cement works at Madukkarai use this limestone as their raw material for cement manufacture. These deposits have not been investigated by the Geological Survey.

MADURA-RAMNAD

Puvandi.—A band of crystalline limestone occurs east of Puvandi (9° 51′:78° 18′), a little to the north of the 13th milestone on the Madura-Sivaganga Road. It strikes E.N.E.-W.S.W. and is seen for a length of 300 ft., with an average width of 30 ft. The material is mostly of very good quality.

Sunnambur.—Another band 2,000 ft. long and 300-700 ft. wide cuts the Puvandi-Melur Road near Sunnambur (9° 52′ 30″:78° 17′ 30″). A furlong to the south of this is a smaller exposure. These are composed mostly of high grade material but the large band contains some impure material towards its western end.

The Puvandi and Sunnambur bands contain 1,000,000 tons of good quality material in a depth of 20 ft. A part of the reserves has been used as road metal (some 40,000 tons have been wasted thus). The Government of Madras have been requested to prohibit the quarrying of this material for road metal.

Tirumal (9° 43′:78° 3′).—At this place, 6 miles N.E. of Kalligudi Railway Station, is exposed a double band of crystalline limestone which can be traced westwards for 2 miles. It contains calciphyre as well as much good material. Another band is seen some six furlongs N.W. of Tirumal having a length of 40 yards and a width of 10 yards. Still another occurrence, in the tank bed of the same village, is much obscured by soil cover.

Two small bands occur west of Kokkulam, about a mile north east of the Tirmul outcrop. Part of this is of good quality and part contains coccolite and chondrodite.

North of Sadumbakulam, on the left bank of the Gondar, a few miles east of Kokkulam there is another occurrence of crystalline limestone.

Pandalkudi (9° 23′ 30″:78° 0′ 30″).—Near Pandalkudi, eight miles south of Aruppukottai and on the Madura-Tuticorin Trunk Road, a large band of crystalline limestone is seen extending for nearly 4 miles in a N.W.-S.E. direction and having a width of 180 to 275 ft. It dips fairly steeply towards the N.E. Much of this is coarsely crystalline and white or pale grey. The western part of the band (about 60 ft. wide) is partly of fine-grained marble and banded graphitic limestone. In the eastern part occurs a handsome pink marble containing coccolite grains. Analyses of samples from the visibly good portions showed that material is of very high grade, with

low magnesia and silica. The central portion is mostly of excellent quality. This occurrence contains, within a depth of 20 ft., at least 750,000 tons of high grade material and 1,500,000 tons with some impurities suitable for cement making.

Palavanattam (9° 33′: 78° 0′ 30″).—This occurrence is about 4 miles east of Virudhunagar on the road to Aruppukkottai. It is largely covered by black soil to a depth of 3 or 4 ft. but has been opened up in numerous places by small quarries over a distance of four miles. The band extends W.N.W.-E.S.E. dipping towards N.N.E. at 50°. Its width is 100 to 200 ft. in different parts. A part of it at the western end is impure, but much of the rest is of good quality. The band is estimated to contain, within a depth of 20 ft., 850,000 tons of high quality and 1,700,000 tons of somewhat poorer material which, however, could be used for cement making.

Chinnayapuram (9° 28′ 30″: 77° 54′ 15″).—This is 8 miles north of Sattur town and 2½ miles N.W. of Tulukkapatti Railway Station. It extends N.W.-S.E. as a band 300-350 ft. wide and about one mile long. To a depth of 20 ft., it is estimated to contain 500,000 tons of high grade and 1,000,000 tons of poorer grade suitable for cement making.

The Pandalkudi, Palavanattam and Chinnayapuram bands are within ten miles of each other and can be worked together for supplying material to chemical industries and for cement and lime making.

There are several small occurrences in the Pandalkudi region, but most of them are of poor quality:

1. North of Pandalkudi and at the south-east end of the tank of the village.
2. East of Kasilingapuram.
3. East and north of Chinnatummakundu.
4. Three thin beds south and east of Tummakundu.
5. ¾ mile east of Podampatti.
6. Near Minakshipuram.
7. One mile S.S.E. of Aruppukottai.
8. Near Reddipatti.

Most of these bands are narrow and their width is between 10 and 60 ft. They are also of small length. The band near Kasilingapuram contains some high grade material. All the bands, including those of Pandalkudi and Palavanattam are capable of yielding beautiful banded and coloured marbles.

A calcareous sandstone or grit of late Tertiary age occurs along the coast of Ramand and continues into Tinnevelly. It has been used in the construction of the famous temple at Rameswaram. It is quarried near Valinokkam (9° 10′: 78° 39′).

TINNEVELLY

Several important bands of crystalline limestones occur in various parts of this district. There are in addition, deposits of calcareous tufa and kankar, calcareous sandstone and coralline limestone, the last two in the coastal tracts.

Crystalline Limestone

Ramayyanpatti (8° 45′: 77° 41′).—Three parallel bands occur along the southern foot of a low quartz ridge (Rastaparambu) about 5½ miles north of Tinnevelly town, cutting across the Sankaranayanarkovil Road. They are exposed from the tank of Nariyuttu (8°48′: 77° 39′) on the west to a mile and a half west of Talaiyuttu on the east. All of them contain high grade limestone especially in the middle.

The western portion, from near the road westwards, is 300 yds. broad and half a mile long. It contains some patches of good material, the rest being calciphyre. The middle portion, 1 mile long, runs E.-W. and is 400 ft. broad. Much of this is of high grade and coarsely crystalline. The eastern portion (east of the Veppankulam-Nanjankulam cart tract) strikes E.S.E. for a mile but only the western extremity of this contains high grade material, the rest being generally impure.

Talaiyuttu (8° 47′ 30″: 77° 43′ 30″).—A band 400-900 ft. broad occurs along the eastern foot of the hills and can be followed for about 2 miles. The general strike is N.N.W.-S.S.E. (steep westerly dip). Part of this is of good quality.

Terku Selliyanallur (8° 53′: 77° 42′ 30″).—An exposure of good limestone extends for 3 furlongs in a N.N.W.-S.S.E. direction from the Chittar southwards. After an interval of some 7 furlongs it is again seen along the strike in a *nala* north of Nellaittiruttu. The average width is 200 ft., the flanks being occupied by quartzites.

Kuttaitattaimalai (599 ft.).—A mile south of his is seen a lime-stone band 50-100 ft. wide which can be traced for about 3 furlongs. The western end shows high grade material.

Nagalapuram (8° 59′: 77° 44′).—Three furlongs northwest of this village (near Kayattar) is a band 1,000 ft. long and 100-150 ft. wide, exposed along the boundary of the Kovilpatti and Sankaranayinar-kovil taluks. The major part is high grade limestone, with some intercalations of calciphyre.

Padmaneri (8° 32′ 30″: 77° 34′).—On the southern flank of the hillock east of Padmaneri is a band 50 ft. wide which strikes into the Kaluttaruttan pottai (·1074 ft.).

Apparkulam (8° 34′: 77° 38′).—A band 75 ft. wide is exposed north of this village and another in a gully on the western bank of the

Pachai Ar, S.W. of Singikulam (8° 35′ 30″ : 77° 38′). A part of this is good limestone. It continues to near Pillaikulam (8° 37′ : 77° 24′ 30″) but the material here is calciphyre and calc-gneiss.

Ambasamudram (8° 42′ : 77° 27′).—An extensive band, 200-400 ft. wide stretches from this place to a mile south-west of Karuttapillaiyur (8° 46′ 30″ : 77° 22′), a total length of some 7 miles. Only small patches in this are pure material, the rest being calciphyre. The impure material is used for lime burning at Ambasamudram.

Pananjadi (8° 44′ : 77° 28′).—A 70-foot wide band is seen between this village and Adaichani (8° 44′ 30″ : 77° 27′ 30″), about 3 miles N.N.E. of Ambasamudram. This contains some good material.

Soolipottai ridge (·418 ft. and ·469 ft.).—Along the northern foot of this ridge, 2 miles E.S.E. of Kila Ambur (8° 45′ 30″ : 77° 24′ 30″) two thin bands are seen running W.N.W.-E.S.E. for a length of 1½ miles, which may be the continuation of the Adaichani band.

Pattamadai (8° 40′ : 77° 35′).—There is a small exposure south of this village and close to the main Tinnevelley Road. It is 1,100 ft. by 200 ft. in area. Another exposure is seen between this village and Kesavasamudram, near a temple. These are generally impure.

Karisalpatti (8° 36′ 30″ : 77° 35′).—Small patches of good limestone are seen near the tank of this village and also near Pillaikulam (8° 37′ : 77° 35′) in a band which is the continuation of the Singikulam band.

Singampatti.—Exposures of limestone are seen near Mela Singampatti (8° 39′ 30″ : 77° 26′), at Mukkavur half a mile to the south-west, at Uttukuli 2 furlongs to the west and a little to the north-west of Singara Bagh. These generally contain impure material.

Alangulam (8° 52′ : 77° 0′ 30″).—Intersecting the Sivalarkulam-Terkuppatti cart rack, north-east of this village, is seen a 200-foot wide band which is over 110 yards long and contains good limestone.

Chettiyapuram (9° 19′ 30″ : 77° 32′).—In the fields east of this village an exposure of good limestone 600 ft. × 300 ft. is seen. It is undoubtedly more extensive as it is much concealed by soil.

Near the same locality and just east of mile 44/3 on the Rajapalayam-Sankarankovil Road, is a series of 8 or 9 parallel bands which can be followed for a length of 550 yds. (N. by E.). Each of the bands is 10-30 ft. wide.

Pandappuli (9° 19′ : 77° 32′).—A small band of limestone is seen west of the village in the fields.

Gopalapuram (9° 19′ : 77° 35′ 30″).—About a mile and a half east of Pandappuli and 3 furlongs west of Gopalapuram a band of good coarse limestone is seen which is 800 yds. long (N.E.-S.W.) and 100-150 ft. wide.

Mt. Zion (9° 22′:77° 33′ 30″).—Between this and Asalapuram is a band having a length of 900 yds. (N.W.-S.E.). It intersects the Rajapalayam Road at mile 47/3.

Viranam (8° 56′ 30″:77° 29′ 30″).—Alongside the Uttumalai Road 1½ miles N.N.E. of Viranam is seen a band exposed for 1,200 ft., with a width of 100 ft. It is obscured by soil and has been quarried on a small scale.

The following estimates refer only to the visibly good portions of the various limestone bands, those containing appreciable quantities of impurities having been left out of account, though portions of these could easily be beneficiated and used. In all cases the estimates are for a depth of 10 ft. only, and represent conservative minimum figures. A number of samples have been analysed, showing the existence of both high-calcium and dolomitic materials.

	Quantity tons.
Ramayyanpatti	250,000
Talaiyuttu (southermost part)	13,000
Terku Selliyanallur	17,500
Kuttaitattai malai	2,300
Nagalapuram	41,000
Apparkulam-Singikulam	3,500
Ambasamudram (1 good patch only)	5,800
Pananjadi	4,600
Pillaikulam	500
Chettiyapuram	8,000
ditto	16500
Pandappuli	800
Gopalapuram	58,000
Mt. Zion	13,000
Viranam	10,000
TOTAL	444,500

There are several occurrences also in the northern part of the district in the Kovilpatti taluk and the neighbouring region. They are described below.

Impure magnesian crystalline limestone bands, 50-75 ft. thick, and up to 100 yards long occur near Kasilingapuram (8° 46′ 30″: 77° 53′ 30″), Ellainayakkanpatti, Singattakurichi, Kil Puvani and west of Naraikinar Railway Station (8° 52′:77° 51′).

Kayattar.—Just east of Kalappaipatti is a band which extends for 3½ miles in a N.W.-S.E. direction to near Kayattar (8° 56′ 45″: 77° 46′30″). It is 200-300 ft. wide and contains good quality material along bands. The good material amounts to some 200,000 tons within a depth of 20 ft., much of it being in the middle, near Terku Mayilodai village.

Villiseri (9° 3′: 77° 53′ 30″).—This is 3 miles N.W. of Kadambur. A band near this village trends in N.N.W.-S.S.E. direction for nearly 3 miles. It is mostly of impure limestone.

Poduppatti (9° 2′ 30″: 77° 59′ 30″).—A band here is seen exposed for 400 ft. and its continuation is seen for 600 ft. near Mallupatti. It is 200-250 ft. wide. The parts which contain good material are expected to yield 45,000 tons within 20 ft. depth.

Ilambhuvanam (9° 9′: 77° 58′).—To the E.S.E. of this village is a band 500 ft. long and 100 ft. wide. To a depth of 20 ft. it is likely to yield over 25,000 tons of good limestone.

Smaller impure limestone occurrences are found near Vadakku Semmapudur (9° 6′: 77° 58′), Tattaparai (8° 49′ 30″: 78° 1′ 30″), Sengottai (9° 16′ 30: 78° 6′), Muttusamipuram (9° 20′: 78° 7′ 30″) and Vannipatti (9° 19′: 78° 11′). Several small bands are also found in the area between Ettaiyapuram (9° 9′: 77° 59′ 45″), Pasuvandanai and Kurukuchalai (8° 56′: 78° 5′ 30″).

Kankar

There are several areas containing beds of kankar and tufaceous limestone. Much of the black soil area (*e.g.*, in Kovilpatti taluk) also contains sparsely distributed kankar nodules. Only those areas in which there are appreciable quantities are mentioned below:

1. About half a square mile around Nainaragaram Railway Station (9° 2′: 77° 20′).
2. Along the streams near Nilidanallur (9° 6′ 30″: 77° 36′), Vadakku Pulankulam (9° 4′: 77° 41′) and other places, for a distance of 10 miles along the streams and half a mile across.
3. Near Uttumalai (8° 59′: 77° 32′) and other neighbouring places in the Uttumalai Zamindari; several miles long and about ½ mile wide.
4. South-west and west of Tinnevelly town, along the tank inflow channel (2 miles by 2 furlongs).
5. N.W. of Pettai near Tinnevelly town, along stream valley. 4 furlongs × 50 yds.
6. Along the steam near Aiyapuram (9° 13′ 30″: 77° 38′) and Talavanpatti (9° 15′: 77° 39′). Two miles by 1 furlong.

7. Along stream north of Ayyaneri (9° 11′ 30″: 77° 49′). 1 mile by 1 furlong.
8. In the fields south of Shuttu Pottai hillock near Vadakku Valliyur (8° 23′: 77° 37′). 3×2 furlongs.
9. South of Samugarangapuram (8° 20′: 77° 42′). 2 miles×1½ furlongs.
10. Stream valleys south of Kasturirangapuram (8° 18′ 30″: 77° 46′). 2½ miles ×1½ furlongs.
11. North of Madapukulam tank near Vijayapati (8° 11′ 30″: 77° 45′). 1½ sq. furlongs.
12. Along steams near Idaiyankudi (8° 18′ 30″: 77° 53′), Suviseshapuram (8° 12′ 30″: 77° 51′) and other places. 4 miles by 1 furlong.
13. North-east of Sattankulam (8° 26′ 30″: 77° 55′) up to Panamparai. 4 furlongs×2 furlongs.
14. In the thorny scrub-jungle south of Pidaneri (8° 32′: 77° 51′ 30″). 1 mile×2 furlongs.
15. Between the tanks of Minakshipatti (8° 41′ 30″: 77° 58′ 30″) and Anaiyaparanallur. 2 furlongs×1 furlong.

These kankar deposits are worked for local use, especially for lime burning. They contain between 40 to 52 per cent. lime, less than 2 per cent. magnesia and varying amounts of silica, alumina and iron.

Calcareous Sandstone

Hard, compact, sub-Recent marine calcareous sandstone and shelly limestone are found half a mile N.W. of Tisaiyanvilai (88° 20′: 77° 52′ 30″), near Megnanapuram (8° 28′: 78° 0′), Tiruchendur (8° 29′ 30″: 78° 7′ 30″) and some other places in the coastal tract. They are usually covered by drifting sands. The thickness of the bed is about 20 or 25 ft. It is drab, light grey, creamy or brownish. The more fine-grained and harder sandstones are quarried and used as building stones. They have been used in the famous Subramanya temple at Tiruchendur and in the churches at Megnanapuram and Idaiyankudi and are found to stand up to the weather well.

The shelly limestones are softer. They are seen along the road to Kulasekharapatnam at Nalumavadi (80° 34′ 30″: 78° 2′), Nallur and Arumuganeri (8° 34′: 78° 5′ 30″), where they extend for 7 or 8 miles inland from the coast. In the same beds they may grade into calcareous grits and shelly gravel.

Coral Limestone

Coral limestone is found as a fringe along the Tinnevelly and Ramand coasts, extending into the numerous small islands in the Gulf of Manar. This limestone is collected and used at Tuticorin and other places for lime burning and also as a building stone. Two types of materials are collected—one being coral fragments (called locally, *shulli*) and the other the porous coral limestone, (called *Nuraikkal*, which means foam-stone). The latter is dressed or cut into blocks for building purposes.

The coral limestone is present over a length of about 80 to 90 miles along the coast and probably extends on the sea bottom for a few miles away from the coast. There are more than 20 islands within a distance of 4 or 5 miles from the coast from which also the limestone is quarried and brought. Apparently this material has been used at Tuticorin for centuries. It is a high grade limestone, analysing 52-54 per cent. CaO, 0·6 per cent. MgO, 0·6 per cent. $Al_2O_3+Fe_2O_3$ and 0–1 per cent. SiO_2. Because of its high quality it can be used for cement making and in the chemical industries.

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CHAPTER XXIX

MAGNESITE

Magnesite or the carbonate of magnesium ($MgCO_3$ containing 47·6 per cent. MgO and 52·4 per cent. CO_2) belongs to the same group of rhombohedral carbonates as calcite and dolomite. It is snow-white, light grey, yellow or buff in colour, with a hardness of nearly 4 and specific gravity of 2·9 to 3. The usual impurities associated with it are iron, lime and silica. It may occur well crystallised (as in limestones) or cryptocrystalline and massive (as in serpentinous rocks).

Commercial deposits are generally associated with serpentines derived from ultra basic (highly magnesian) igneous rocks such as dunites and peridotites. By hydrothermal alteration through the agency of water and carbon-dioxide from igneous emanations, the magnesia content of the original rocks is converted to magnesite and serpentine.

Magnesite is used in the manufacture of magnesium salts, metallic magnesium and caustic and dead-burnt magnesia.

Magnesium metal is made by the electrolysis of magnesium chloride which may be made from magnesite or recovered from brines and sea-water. All these were used during the War as raw materials. The electrolysis is carried out in cells of 8,000 to 10,000 Kg. capacity at a voltage of around 8 and ampereage of 15,000 to 50,000. The current consumption per pound (avoirdupois) of metal produced is about 8-9 Kwh. Another process uses magnesia which is reduced in an electric furnace by means of ferro-silicon.

Magnesite dissociates at a lower temperature than calcite (limestone). It is calcined in a shaft-klin or rotary kiln to yield either caustic magnesia or dead-burnt magnesia, the former at 700-1200° C. and the latter at 1500° C. Caustic magnesia contains a small amount of carbon-dioxide (because of incomplete dissociation) and is active in the presence of water and carbon-dioxide. The dead-burnt product obtained through complete calcination is a dense recrystallised oxide (periclase) which is not active under ordinary conditions.

Uses

Magnesium metal is used in the form of light-weight alloys in aircraft, scientific instruments, cameras, etc. Magnesium powder is an important ingredient of incendiary bombs as it develops a high temperature when burning. Magnesium wire and filament are used for flares for signalling and for flash-light photography.

Caustic magnesia is used for making oxychloride cement by treating it with a solution of magnesium chloride. It is said that recent

technological advances have contributed greatly to the improvement of the product. Caustic magnesia is also utilised as a filler in the paper, paint and rubber industries and for making magnesium salts.

The dead-burnt product is used as such or in the form of bricks to line the hearth and walls of furnaces. A small percentage of iron is desired in the magnesia for making magnesia bricks and often a small quantity of iron oxide is added, as necessary, during the manufacture of bricks. Magnesia, in the fused form, is also used in the nonferrous metal industry.

Deposits

The occurrence of magnesite has been recorded in the Bellary, Kurnool, Trichinopoly and Salem districts and in Coorg, but workable deposits are confined to the Salem-Trichinopoly region.

Bellary.—Foote noticed the presence of small veins of magnesite traversing ferruginous quartzites at the south-eastern end of the Sujokonda near Daroji (15° 15′ 30″ : 76° 40′).

Kurnool.—The Quinquennial Review of Mineral Production of India for 1909 to 1913 (*Rec. Geol. Surv. Ind.*, XLVI, 135) states that large quantities of magnesite are associated with the steatite deposits of Muddavaram (15° 30′ : 78° 6′) and Musalacheruvu near Betamcherla. It is apparently too much mixed up with calcareous and clayey impurities to be worked profitably. The deposit has not been examined in detail. It appears to occur in the Vempalle dolomitic limestone.

Coorg.—The same publication (*Rec. Geol. Surv. Ind.*, XLVI, 134) mentions the presence of veins of magnesite in peridotite at Seringala (12° 22′ 30″ : 75° 31′) and at a locality on the Cauvery a little above Fraserpet (12° 27′ : 75° 58′). No details are available about these occurrences.

Salem-Trichinopoly.—The deposits extending from near Sâlem to the foot of the Shevaroys, and known locally as *Sunnambu karadu* in Tamil (named ' Chalk Hills ' by the English) must have been known to and utilised in a small way by the local people long before the officers of the East India Company and European travellers took an interest in them. Dr. B. Heyne seems to have been the first amongst these to record the presence of magnesite here, at the beginning of the 19th century. A few years later, Dr. Macleod used calcined magnesia as plaster for the interior of buildings and also in 1825 to repair parts of the Fort St. George at Madras. Later still, Col. Slim of the Engineers used a cement composed of 2 parts of calcined magnesia and 1 part of sand and pronounced it to be more resistant to weather than ordinary lime plaster. At that time (about 1830) a ton of magnesia cement (? calcined magnesia) was said to cost Rs. 80-90 at Madras. Dr. Macleod calculated that magnesite found near

Trichinoploy (at Yedichicolum on the Cauvery according to Newbold) could be calcined and brought to Madras at a cost of about Rs. 40 per ton.

P. M. Benza has given a description of the Chalk Hills deposits in his paper published in 1836. Soon after that Newbold visited the Chalk Hills. He has stated that the magnesite occurs over an area of 8 sq. miles, as veins having a dark grey colour outside and with thickness up to 3 ft. The altered dunite is described by him as 'hornblende-schist'. He found chert and chalcedony in association with the magnesite. The magnesite, on analysis, gave 48·34 per cent. magnesia, 51·66 per cent. carbonic acid, 0·30 per cent. silica, 0·80 per cent. water, no lime, and only traces of alumina, manganese and iron oxides. Newbold has stated (as also Benza) that magnesite occurs at Yedichicolum near Trichinopoly (probably the forgotten name of a hamlet near Tiruppangili, 10 miles N.W. of Trichinopoly) and near Coomerpollium (presumably the occurrence at Thevur near Kumarapalaiyam close to Bhavani).

The Salem and Trichinopoly districts were geologically surveyed by Dr. W. King and Mr. R. Bruce Foote in the early sixties and to them we owe the first adequate descriptions of the geology of these deposits. They also mention the occurrence of magnesite veins at the following places:

> Muttunayakanpatti near Valaiyappatti; 1 mile S. of Pavittiram; East of Iswaramalai; 1 mile south of Kanjaripatti (Konerippatti); between Tirupangili and Tirampalayam; and ½ mile S.E. of Valikandapuram.

Sir Thomas Holland examined parts of the Salem district in connection with his study of the iron ores and the iron industries about 1890 and was followed by Mr. C. S. Middlemiss who mapped and studied the magnesite deposits in detail. Holland came to the conclusion that the magnesite was formed by the action of carbonic acid at high temperature and pressure on the dunite rock in which it is found, and that therefore the mineral would be coextensive with the rock at depth. Middlemiss estimated the area covered by the magnesite to be 4½ sq. miles; in this the mineral formed one-third to one-half of the rock (by volume) in an area of about 130 acres, and one-tenth to one-sixth of the rock in an area of 1,140 acres, the rest of the area containing only sparsely distributed veins.

H. G. Turner commenced the commercial development of the Chalk Hills deposits in 1900 or 1901 and formed the Magnesite Syndicate Ltd., who now hold a large part of the area under a mining lease, and have been producing magnesite since 1902. Most of the output is calcined at the mines and practically all of its exported to other parts of India and overseas.

8 JUL 1952

Below are given short notes of the deposits examined by the Geological Survey of India during the last few years.

Kanjanur.—Two miles north of Dasampatti Railway Station and half a mile north of Kanjanur (12° 16′:78° 26′) are some hillocks crossed by the railway between miles 154 and 155. They show a lateritic rock at the surface underlain by dunite. One of these hillocks, the Sanjivirayankaradu, shows numerous veins traversing the rock, the veins being 2 to 5 inches thick. Magnesite has so far been proved only in an area 200 yds. and further prospecting work is necessary to prove the full extent of the deposit.

Siranganur.—Just north of Siranganur village (11° 44′:78° 46′ 30″) close to the Taramangalam-Nangavalli Road magnesite occurs over an area 6 furlongs long (N.E.-S.W.) and 200-400 yds. wide. Some steatite and rather brittle asbestos also occur in the dunitic rock. The richest magnesite-bearing part is in the north-east where the veins are up to 12 inches thick. The reserves, to a depth of 50 ft., are of the order of 105,000 tons.

Kundamalai.—About 2½ miles west of Jalakandapuram there is a deposit at the south-western foot of the Kundamalai (11° 43′:77° 51′) in an area 150 yds. long and 75 yds. wide. The veins are up to 4 inches thick and sparsely distributed. The magnesite is rather high in lime, and may amount to 1,000 tons in a depth of 50 ft.

Thevur.—About 5 furlongs west of Thevur (11° 33′ 30″:77° 45′) magnesite is seen as thin veins in an area of about 2 acres.

Chettipatti.—Two similar patches of ultrabasic rocks with magnesite veins are seen west of Chettipatti (11° 33′ 30″:77° 47′). The northern patch is 350 ft. × 250 ft. in area and contains thin veins. The southern patch, which is a furlong south of the northern, shows closely spaced veins, 1 to 2 inches thick in an area of 2 acres. This may be expected to contain 50,000 tons within a depth of 50 ft.

Iswaramalai.—To the west of the Iswaramalai (11° 33′:78° 25′) a few miles W.S.W. of Malliyakarai near the border of Salem and Trichinopoly, a small area of an acre or two is known to contain magnesite. This has not been visited recently.

Chalk Hills.—By far the most important deposits are those called the Chalk Hills (11° 42′:78° 11′), a short distance to the west of Salem town. These consist of a northern and southern area of magnesite-bearing dunitic rocks, separated by a tongue of schists forming the Karangaradu hill. The northern area is about 4·4 sq. miles and the southern 1·1 sq. mile. The thickness and frequency of veins are variable from place to place. The veins are up to 3 ft. thick. On an average, the magnesite forms 6 to 10 per cent. of the volume of the rock. The reserves, to a depth of 100 ft. from the surface may be taken as 66 million tons in the southern area and 16·5 million tons in the northern area.

Kanjamalai.—At the north-eastern end of Kanjamalai, about half a mile east of Siddharkovil (11° 37′ 30″ : 78° 2′) there is a small area of ultrabasic rock containing a little magnesite. This is of no importance.

Sirappalli.—A good deposit of magnesite occurs in a low ridge about half a mile west of Sirappalli (11° 12′ : 77° 57′ 30″). The country rock is biotite gneiss and garnet-amphibolite. The ultrabasic rock forms the low ridge (·698) trending E.-W. for about 6 furlongs. The eastern part is richer in magnesite than the western and contains veins up to 12 inches thick, the average being about 3 inches. The total area occupied by the deposit is about 28 acres and the reserves to a depth of 50 ft. have been calculated as 325,000 tons.

Rajampalaiyam.—Three small patches of ultrabasic rocks, traversed by thin veins of magnesite are seen between Rajampalaiyam (11° 12′ : 77° 56′) and the hill ·698 of Sirappalli. Lumps of magnesite were also seen in cultivated fields three furlongs N.W. of Rajampalaiyam. The deposits are not promising.

Nadandai.—Half a mile east of Nadandai (11° 12′ : 77° 58′ 30″), beside the cart track connecting it with the main Tiruchengodu-Paramati Road, there is an area of 800 yds. × 50 yds. in which veins of fair quality are seen. This area is worth prospecting as it may yield a useful though small tonnage.

Magnesite lumps are noticed in the cultivated fields half a mile east of the Tiruchengodu-Parmati Road and close to the Nadandai-Mettur cart track. This area is soil-covered and should be prospected by pits to ascertain the extent of the deposit.

Kavalkurichchi.—Thin veins of magnesite are seen in serpentinised rocks in two small areas, one just S.E. of Kavalkurichchi (11° 9′ : 77° 57′ 30″) and the other, half a mile S.E. of Nattaiyampalaiyam. The deposits are rather poor.

Jangamanayakanpatti.—Five furlongs east of Jangamanayakanpatti (11° 12′ : 78° 2′ 30″) there are two or three low knolls exposing ultrabasic rocks. Magnesite veins of good quality are seen in the area west of 25r marked on the survey of India sheet 58 1/4 (1″ = 1 mile), for a length of three-fourths of a mile (east-west) and an average width of 120 ft. Some of the veins are up to 4 ft. thick and 15 to 20 ft. long. A part of this deposit is estimated to yield at least 10,000 tons within a depth of 50 ft.

Puliyampatti.—The high ground half a mile north of this village shows a strip of ultrabasic rocks one mile long (East-West) and two furlongs wide. The surface of the rock is partly lateritised and partly obscured by soil, but indications of magnesite are seen frequently. This deposit is worth prospecting as it appears to be promising.

About a mile north-east of this village also a small outcrop of magnesite-bearing rock, 100 ft. × 100 ft. in extent is seen. This is also obscured by soil.

Kuppampalaiyam.—A small area, 300 ft. × 100 ft. of magnesite-bearing rock occurs two furlongs north-east of this village (11° 10′ 30″: 78° 13′). This is not promising.

Valaiyappati.—About 3 miles N.N.E. of Valaiyappati (11° 7′ 30″: 78° 14′) there are small deposits of magnesite on a low ridge, the western portion of which (south and W.S.W. of hill ·657) shows good veins, 10 to 12 inches thick in an area 250 yds. × 100 yds. This area is estimated to contain at least 18,000 tons, but as there is much soil cover, the deposits may be much larger.

Villiyappanpatti.—A mile and a half E.N.E. of Villiyappanpatti (11° 9′: 78° 6′ 30″) near the foot of the Tolurkaradu (·1445) another small area 100 ft. × 100 ft. occurs. Near the temple on the top of this hill, pieces of magnesite are seen in a small exposure of ultrabasic rock there.

Ariyurpatti.—(11° 13′ 30″: 78° 0′ 20″). At the foot of the hillock (·550) east of this village thin veins of magnesite are noticed in a small area.

Varappalaiyam.—(11° 12′ 30″: 78° 4′).—North-west of this village and close to the cart track leading to Kirambur a small deposit is seen. Another similar area occurs two furlongs west of Tokkattampalaiyam (11° 13′: 78° 7′), where a vein 1 foot thick was seen in a well section. Pieces of magnesite are also seen in the fields here but the rocks are obscured by soil.

The following occurrences are in the contiguous area coming within the limits of the Trichinopoly district north of the Cauvery river.

Pavittiram.—East of the hamlet of Valasiramani, about a mile and a quarter south of Pavittiram (11° 8′: 78° 22′) in the Musiri taluk, magnesite is seen in a small area. The occurrence however seems to extend to Jambumadai a mile away, but is much obscured by soil. The outcrop referred to above is 300 ft. × 300 ft. and contains good veins estimated to yield 5,000 tons within a depth of 50 ft. The area is worth detailed prospecting as it is likely to be fairly extensive.

Konerippatti (11° 11′ 30″: 78° 27′).—The raised ground one mile south-east of this village shows ultrabasic rocks containing this veins in area of 300 ft. × 150 ft. This is also partially obscured by soil.

Tiruppangili.—Half a mile east of Tiruppangili (10° 56′: 78° 39′) which is 10 miles N.W. of Trichinopoly, there is a slightly elevated piece of ground in which veins of magnesite are seen. Judging from the exposures, this deposit does not appear to be promising. Yedichicolum mentioned by Benza and Newbold may be a hamlet near this locality but is not shown on modern 1-inch sheets.

Valikandapuram (11° 19′: 78° 55′).—King and Foote have recorded the existence of a small occurrence of thin magnesite veins associated with travertine near this place. This has not been visited recently.

Quality of the Magnesite

As mentioned already, the magnesite is derived from the alteration of ultrabasic rocks in which they now form veins. The material from the larger veins is fairly hard and can be easily separated from the accompanying friable serpentinised dunite, but the thin veins are not so separable. The analyses given below are those of the material got from the thicker veins.

Analyses of Magnesite

(All figures—per cent.)

—	1	2	3	4	5	6	7
SiO_2	1·17	0·22	0·29	1·85	0·70	1·69	2·40
R_2O_3	0·14	0·30	0·55	0·08	0·40	0·16	0·56
CaO	0·78	*nil*	0·83	0·81	0·60	1·20	17·32
MgO	46·28	47·35	46·42	46·41	47·85	45·46	31·51
H_2O	1·30	0·27	0·16	0·20	0·18	0·04	0·02
Ign.	50·10	51·44	50·71	50·64	50·40	51·54	48·14
TOTAL	99·77	99·58	99·06	99·91	100·13	100·09	99·95

—	8	9	10	11	12	13	14
SiO_2	0·78	0·72	1·02	0·48	12·16	2·62	4·06
R_2O_3	0·26	0·12	0·47	0·16	1·00	1·10	0·60
CaO	5·34	0·56	8·69	10·30	1·44	0·50	1·12
MgO	41·26	47·10	39·36	37·34	40·07	45·37	44·31
H_2O	0·27	0·10	0·01	—	—	—	—
Ign.	52·05	51·51	49·62	51·66	—	—	—
TOTAL	99·96	100·11	99·17	99·94	—	—	—

1. Chalk Hills. Cargo sample (Pattison).
2. do. } Quoted by Dains.
3. do. }
4. do. Southern area (Magnesite Syndicate) Govt. Test House, Alipore.
5. do. Northern area (Chatti chavadi) Govt Test House, Alipore.
6. Siranganur (N.K. N. Aiyengar and V. Subramanyam)
7. Kundamalai do. do.
8. Valaiyappatti do. do.
9. Sirappalli do. do.
10. Pavittiram do. do.
11. Jangamanayakanpatti (V. Subramanayam).
12. Kanjur—Dasampatti (G. S. I.).
13. Thevur do.
14. Chettipatti do.

In the analyses there is generally a small quantity of lime, which in a few cases amounts to an appreciable percentage. In the R_2O_3 (alumina+iron oxide) iron is very low, usually about one-tenth of one per cent. or less, the rest being alumina.

Reserves

The reserves have been calculated, on a very conservative basis, for the more important deposits taking into account only workable veins having a thickness of one inch or more. In all cases a depth of 50 ft. is assumed except for the Chalk Hills for which a depth of 100 ft. is assumed. Should it be possible to recover the fine material from the thin veins and ramifying veinlets and disseminated material, the reserves would be considerably increased.

	Tons.
Chalk Hills (northern area)	66,000,000
Chalk Hills (southern area)	16,500,000
Siranganur	105,000
Kundamalai	1,000
Valaiyappatti	18,000
Jangamanayakanpatti	10,000
Sirappalli	325,000
Pavittiram	5,000
Chettipatti	50,000
TOTAL	83,014,000

Production and Prospects

The recorded figures of production are given from the commencement of operations of the Magnesite Syndicate in 1902. The total to-date will amount to about three-quarters of a million tons.

Year.	Tons.	Year.	Tons.	Year.	Tons.
1902	3,540	1917	18,192	1933	11,131
1903	825	1918	5,773	1934	11,859
1904	1,315	1919	13,012	1935	12,840
1905	2,063	1920	11,300	1936	12,966
1906	1,832	1921	17,152	1937	23,782
1907	186	1922	18,417	1938	23,052
1008	7,534	1923	19,336	1939	29,903
1009	737	1924	24,427	1940	37,304
1910	5,182	1925	29,620	1941	36,527
1911	3,490	1926	28,676	1942	41,639
1912	15,379	1927	16,966	1943	42,734
1913	14,086	1928	22,542	1944	38,025
1914	399	1929	22,134	1945	28,047
1915	7,450	1930	15,563	1946	43,628
1916	17,540	1931	4,978	1947	
		1932	13,492	1948	

The high quality of the Salem magnesite is well known. Only a small quantity is used in India for making refractories the rest of the output being exported to Europe. An effort should be made to retain much of the output within the country as it could be used for the manufacture of magnesium metal, oxychloride cement and magnesium salts.

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CHAPTER XXX

MAGNETITE

Magnetite (Fe_3O_4), the magnetic oxide of iron is a common mineral in igneous and metamorphic rocks, usually found in small quantities as grains. It is found in large quantities in magnetite-quartzites which form considerable masses in Salem and Trichinopoly and are also known to occur in some areas in Arcot, Guntur and other districts. The large occurrences are useful as iron ores (*see* under 'Iron ore').

One or two small patches of lodestone (magnetite with natural magnetism) have been noticed in the lowest band of ore at the southern foot of the Kanjamalai near Virapandi Road Railway Station.

Crystals of magnetite have been recorded to occur in the following places. They are usually a quarter to a half inch in size but in exceptional cases more than one inch across:

(*a*) Sparsely distributed in a thin band of Vempalle limestone overlying a trap sill, about a mile and a half N.N.W. of Chimalpenta (14° 26′: 78° 35′ 30″), Cuddapah district.

(*b*) In slates in the hillock half a mile E.N.E. of hill ·908 which is 2 mile S.E. of Rayavaram (15° 43′: 79° 19′) in Kurnool district.

(*c*) At the junction of crystalline limestone bands with pegmatite intrusives and in the pegmatites in the southern part of the limestone exposures near Varavanai. (10° 45′: 78° 13′ 30″), particularly near the temple ¾ mile north Odaiyappatti along the road to Yanakkulattupatti in Trichinopoly district. Some crystals here are 1 to 1¼ inch across.

(*d*) Grains and small pieces of magnetite are found in granitic and pegmatitic rocks near Kattalaiyur (8° 50′ 30″: 77° 26′), Mettur (8° 52′: 77° 22′) and their neighbourhood in the Tinnevelly district. The sandy soil here shows a fair amount of the mineral.

Uses

Magnetite has been used in India during the War as a substitute for 'emery' as abrasive. Graded magnetite grains are said to have been extensively used by rice mills for polishing rice. The mineral also finds use in the Ayurvedic system of medicine for the preparation of powders for internal use.

CHAPTER XXXI

MANGANESE

Manganese is one of the most important subsidiary metals in the iron and steel industry and enters into the composition of pig iron and steel as well as alloy steels. It has also uses in the chemical field.

The chief ores of manganese are mainly oxides. They are mostly black in colour and may contain some iron also.

Name.	Composition.	p. gr.	Mn.%
Pyrolusite . . .	Peroxide of Mn. (Powdery)	—	63·2
Polianite . . .	Peroxide of Mn. (Crystalline)	4·8	63·2
Psilomelane . . .	Oxide of Mn. with some water, Na, K, Ba, Fe. (Concentric and botryoidal).	3·7—4·7	45—60
Braunite . . .	Oxide and silicate.	4·8	62
Jacobsite . . .	(Mn. Fe.)$_3$ O$_4$	4·75	—
Hausmannite . .	Mn O$_4$	4·8	72
Manganite . . .	MnO (OH)	4·3	62·5
Hollandite . . .	Manganate of Mn, Be, Fe.	4·7—5·0	—
Sitaparite . . .	Oxide of Mn. with Fe. and Ca.	5·0	—
Rhodocrosite . . .	Manganese carbonate.	3·5	61·7

The minerals which make up the bulk of Indian ores are pyrolusite, psilomelane and braunite. Hausmannite in a pure form has not been found in India but its mixture with jacobsite, known as Vredenburgite is found in the Vizagapatam deposits. Sitaparite, hollandite and rhodocrosite are comparatively unimportant.

Many of the world's deposits of manganese ore are of sedimentary origin, forming beds, pockets or disseminated materials in sandstones and shales. They are also found in schists and gneisses, of probably sedimentary origin, in the form of lenses and veins. The deposits in India are associated with and derived from Archaean schistose rocks.

There are three types found in India. The *gondite type*, associated with gondite, a rock composed of quartz and manganese garnet is widely distributed, in Northern India. The *kodurite type* is associated with a hybrid rock kodurite, composed of quartz, feldspar, manganese-garnet and pyroxene and generally rich in apatite. It is thought to have resulted from the invasion of manganiferous

sediments by granitic rock. The third or *lateritic type* is due to the concentration of manganese content of the underlying rocks in the form of a lateritic material at the surface.

The ores in the first two types have been to some extent altered by atmospheric agencies and water and reconstituted at the surface. But they can be expected to extend to some depth. The lateritic ores, however, are confined to a small depth at the surface as they are entirely products of the lateritic mode of alteration and can extend only to such depth as is under the influence of surface waters.

Manganese ores generally contain more or less iron and grade into iron ores containing some manganese. Those containing more than 35 per cent. manganese (metallic) are classed as manganese ores; those with 10 to 35 per cent., ferruginous manganese ores; those with less than 10 per cent., manganiferous iron ores.

The manganese ores are themselves classed as first, second and third grade. The first grade contains over 48 per cent., the second 45 to 48 per cent. and the third below 45 per cent. manganese. In the trade there are penalties attached to silica, phosphorus and sulphur exceeding certain minima, while a premium may be given for ore containing exceptionally high percentage of manganese.

Uses

A small quantity of the metal is used as alloying element in stainless steel, copper-nickel alloys, bronzes and in aluminium alloys. Much the greater part of the ore produced is converted into ferro-manganese in the blast furnace or electric furnace. Low phosphorus ore is preferred for this purpose. About 2·5 tons of manganese ore are needed to produce one ton of ferro-manganese containing 70-80 per cent. manganese. Another iron-manganese alloy called *spiegeleisen* is also produced, containing 18-22 per cent. manganese. *Silico-spiegel* is an alloy containing 60-65 per cent. iron, 18-22 per cent. manganese and 5-12 per cent. silica.

In ordinary carbon steel a small amount of manganese (1·3 to 1·6 per cent.) is introduced in the form of ferro-manganese, its function being that of a de-oxidiser and de-sulphuriser. Manganese is added in much larger amounts to make manganese-steel (10-12 per cent. manganese). Manganese steel is tough and hard and is useful in machine parts subject to abrasion.

There are several non-ferrous alloys containing manganese. Brasses and bronzes containing 2-3·5 per cent., and aluminium alloys containing 1-3 per cent. manganese, are resistant to corrosion and abrasion. An alloy containing copper, 4 per cent. nickel, 8-12 per cent. manganese, called *manganin*, is used for standard resistances in electric circuits and instruments.

For chemical purposes a very high grade ore with low iron and other impurities is specified. The physical condition of the ore, and high peroxide content are important if it is used in dry cells. Small quantities of high grade ore very low in iron are used in the glass industry as a decolouriser, and in the ceramic industry for producing coloured enamels and glazes. Manganese oxide and other compounds (manganate, permanganate, chloride, etc.), have various uses in industry—paint, leather, textile, etc.

Deposits

Vizagapatam.—As early as 1852 some specimens of manganese ores were sent from Vizianagaram and Bimlipatan and analysed in Britain :—

—	Vizianagaram per cent.	Bimlipatam per cent.
Slicic acid	8·300	9·090
Peroxide of Iron	12·910	11·720
Lime	—	1·244
Magnesia	2·339	0·668
Water	0·539	0·432
Red oxide of manganese	73·786	76·177
Oxygen	1·864	0·665
	99·738	99·986
Manganese	53·428	54·929

The reports by the juries of the Madras Exhibition of 1855, where manganese ores from this district were exhibited, mention the fact that manganese ores were available in large quantities near Vizianagaram and Bimlipatam. High grade ore was found at about the same time near Chiprupalle, according to the 'Gazetteer of Southern India' published by Pharaoh & Co. in 1855. In the District Manual of Vizagapatam, D. E. Carmichael states that manganese ore from Bimlipatam was sold there at 2 annas per maund. Dr. W. King noticed manganese ore being used as road metal at a spot 6 miles north of Vizianagaram on the Palkonda road and near Ramachandrapuram in the Bobbili Zamindari.

A syndicate was formed in 1891 to work the deposits near Kodur, which produced 674 tons and 3,130 tons respectively in 1892 and 1893. It was converted in 1895 into the Vizianagaram Mining Co. Ltd. An account of the work of the company up to 1896 has been

given by H. G. Turner (in Journal of the Iron and Steel Institute) formerly Collector of Vizagapatam and at that time a Director of the Company (and probably the same gentleman who organised the Magnesite Syndicate working in Salem?). Other concessions were obtained during this period by Messrs. Gordon Woodroffe & Co., Messrs. A. S. N. Co. and by the Vizianagaram Mining Co. During 1905 and 1906, the Madras Manganese Co., later called the Bobbili Mining Co. started work on several new deposits near Garividi and Chiprupalle. The Vizagapatam deposits have in some years produced over one lakh tons of ore and given employment to a labour force of over 8,000 people.

Sir L. L. Fermor has described the deposits (24 in number) which had been opened up by 1905, in his well-known Memoir, to which reference may be made by interested readers. Only two of the deposits are described briefly below.

Kodur (18° 16′ 30″ : 83° 33′) is in the middle of a belt of deposits extending for 3 miles from Garividi to Sadanandapuram. The quarry at Kodur was 200 yards long in lithomargic clays derived from the alteration of the original rocks. The several lens-like ore bodies here showed a tendency to coalesce when followed downward. On the north-east side of the deposits is a zone of wollastonite-scapolite-gneiss, with khondalites cropping out further away. On the south-west side the same rocks are repeated, the two sides apparently forming the arms of a syncline. The ore-bearing kodurite appeared to form an intrusive body breaking through the syncline. The lithomarge enclosing the ore contained also pockets of kaolin and inclusions of unaltered kodurites and crystalline limestone. The Kodur deposits were the first to be opened in 1892, and had produced 370,852 tons by the end of 1913.

The deposit at Garbham is probably the largest in India. Manganiferous iron ore capping the deposit here had probably been used for centuries by the local artisans for smelting iron. The deposit, when originally opened up, formed a ridge rising 80 ft. above the general ground level and had a length of 2,200 ft. But, if it were continuous with the workings to the W.N.W., the total length would be 4,500 ft. The ore body showed a southerly dip and a thickness of 167 ft., of which 100 ft. was ore and the rest was lithomarge. The ore consisted of psilomelane, pyrolusite and mangan-magnetite. The deposits were opened up in 1896 and had produced over 736,000 tons by the end of 1913.

The deposits opened up by 1905 and described by Fermor are the following :—

1. Garividi.
2. Koduru.
3. Duvvam.
4. Devada.
5. Sadanandapuram.
6. Sivaram.
7. **Perapi.**
8. Itakerlapalli.
9. Mulagam.
10. Govindapuram
11. Garbham.
12. Kotakarra.
13. Gadasam.
14. Avagudem.
15. Aitemvalasa.
16. Gotnandi.
17. Bondapalli.
18. Garraraju Chiprupalli.
19. Perumali.
20. Ramabhadrapuram.
21. Tanduru.
22. Chintalavalasa.
23. Thonaum.
24. Other small deposits.

By 1908 another two dozen deposits had been opened up, mentioned below :—

1. Gadabavalasa.
2. Lakshmipuram.
3. Nimmalavalasa.
4. Sarvesvarapuram.
5. Viziarampuram.
6. Batuva.
7. Visvanathapuram.
8. Chatlapuram.
9. Ravivalasa.
10. Baidapalli.
11. Chinna Ranyam.
12. Kothavalasa.
13. Chokkarapalem.
14. Gotnandi.
15. Vedullavalasa.
16. Gummadam.
17. Mukku Narasannapeta.
18. Regati.
19. Dannanapeta.
20. Gunpam.
21. Palavalasa.
22. Duggivalasa.
23. Kondapalem.
24. Sivandhoravalasa.
25. Butharayavalasa.

The ores of the Vizagapatam district are mainly composed of psilomelane with subordinate braunite and occasional manganmagnetite. Braunite sometimes assumes importance as a. Garbham, while pyrolusite is common at Kodur and Sadanandapuram. The analytical data for the deposits of the Chiprupalle taluk, which include the most important ones, are:—

—	Limits.	Mean.	Average Kodur.	Average Garbham.
Manganese	32·21—49·05	42·96	47·11	45·39
Iron	4·80—15·70	11·22	9·70	9·99
Silica	1·10—10·30	4·29	3·15	4·43
Phosphorus	0·13—0·48	0·27	0·90	0·45
Moisture	0·50—1·85	0·90	—	—

Sandur State.—The earliest reference to the existence of manganese ores in this State seems to have been made by Newbold. Ore from here was exhibited in the Madras Exhibition of 1855 and 1857. During his survey of the Bellary district, R. B. Foote noticed the existence of fairly abundant manganese ore nodules in altered phyllitic rocks on hill slopes near Ramandrug and a few other localities. In 1904 and 1905, Mr. A. Ghose discovered numerous deposits in the State—including those at Ramandrug, Kamataru (Kammadheruvu) and Kumarswami, and opened up the Ramandrug Main Bed on behalf of Messrs. Jambon & Cie. The General Sandur Mining Co. took over the rights of Jambon & Cie and acquired the monopoly to work the manganese and iron ores of the State, paying a royalty of 6 annas per ton on manganese and half an anna per ton on iron ore with a minimum of Rs. 25,000 per annum. The Swamihalli and Kammadheruvu jagir areas were, however, subject to a royalty of 6 annas per ton of iron ore mined.

Accounts of these deposits have been given by A. Ghose, R. O. Ahlers and Sir L. L. Fermor from which detailed information can be obtained.

The Sandur Hills and the Copper Mountain of Bellary form two parallel folds trending N.W.-S.E. and joined together at the centre. The Sandur fold is oval shaped, with a length of 36 miles and a maximum width of 12 miles. It forms an elliptical hollow area bounded by ridges which are broken at the sides by the Narihalla (a tributary of the Tungabhadra) forming gorges called Oblagandi (through the ridge on the south-west) and Bhimagandi (through the ridge on the north-east). The north-western end of the fold projects into the Hospet taluk of the Bellary district for some 7 or 8 miles while the south-east end projects into the Kudligi taluk (Bellary) and the adjoining Chitaldrug district (Mysore State).

The rocks of the fold are mainly phyllites which have largely been weathered to lithomargic material, and ferruginous quartzites and jaspers. These rocks have to some extent been replaced and enriched by manganese and iron ores. There are also sills of basic igneous rocks now seen as epidiorites, and some granitic intrusives.

The deposits were assembled as shown below into 10 groups by Ghose, the numbers within brackets being the number of deposits in each group :—

Kammat haruvu (28)	Subbarayanahalli range (8)
Hanumantana haruvu (4)	Tumbaragaddi forest (3)
Tonashigri forest (6)	Kanevihalli range (11)
Mannal Haruvu (10)	Ramandrug range (23)
Kumaraswami (8)	Timmappa gudda (1)

Fermor has put the deposits under four main groups :—

1. Ramandrug 9 deposits.
2. Kanevihalli 10 deposits.
3. Kumaraswami 20 deposits.
4. Kamataru 27 deposits.

The deposits are largely on the western arm of the synclinal on its crest and western slopes. The Ramandrug group is found on the Ramandrug plateau and the western slopes. The second group extends on either side of the Oblagandi gorge. The Kumaraswami deposits are partly on the plateau but extend down the slopes in the south-western corner of the State. The Kamataru deposits are on the southern side.

The outcrops are generally lichen-covered and show a tendency to stand up against the softer decomposed schists and may therefore give an erroneous idea of their size and importance. They conform to the bedding of the rocks from which they have been derived. but are superficial and extend down perhaps to a maximum depth of 100 ft. from the surface. Below and around the deposits the original rock has been altered to lithomargic clay. Local concentration of the manganese content has also given rise to pockets and lumps in the phyllitic rock. The ore is sometimes associated with magnetite grains which represent an original constituent of the parent rock. In some places there are deposits of iron ore (hematitic) or mixed iron and manganese ore. The ore bodies often retain the structural features of the parent rocks and are regarded as due to their lateritic alteration.

The chief minerals present are wad and psilomelane with subordinate pyrolusite and manganite. The typical ore is a mixture of psilomelane and wad and some grains of magnetite. Psilomelane seems to be the final product of alteration through the intermediate stage of wad.

Mr. M. S. Venkatram mapped and examined these deposits in 1946-47. He has divided them into four groups, *viz.*, Kammadheruvu, Kumaraswami, Kanavehalli and Ramandrug, and estimated the reserves to a depth which varies from 25 to 50 ft. The composition of the ores and the reserves are given below :—

Range of composition

—	I	II	III	IV
SiO_2 . . .	0·70—3·50	0·40—2·16	0·46—3·66	0·41—1·16
Al_2O_3 . .	2·73—15·06	0·01—10·04	2·22—11·69	3·03—9·83
P . . .	0·06—0·25	0·02—0·16	0·09—0·11	0·12
Mn . . .	29·24—47·39	38·13—61·60	21·51—49·46	33·65—46·11

The estimated reserves are as follows :—

	Tons
I. Kammadheruvu group	871,100
II. Kumaraswami group	1,528,600
III. Kanavehalli group	86,000
IV. Ramandrug group	217,500

Of these groups III and IV have been extensively worked by the General Sandur Mining Co., and the above figures represent the reserves still available. Part of the reserves of group IV are rather difficult to recover as the cost of working will be high.

Bellary.—The Dharwar-Shimoga band of schists passes through the north-western part of the State and contains ferruginous quartzites and manganese ores on the Teligi hill, some 10 miles N.N.E. of Harihar.

The north-western end of the Sandur syncline projects into this district and contains manganese ore in the Kalhalligudda in Hospet taluk. There are also some deposits in the hills of the Tonashigri and Tumraguddi reserved forests which form the south-eastern continuation of the Sandur syncline in the Kudligi taluk. A small occurrence of manganese ore was found by J. M. Maclaren at the northern end of a ridge of ferruginous quartzites 6 miles west of Huvinhadagalli. This forms part of the Dambal-Chiknayakanhalli band of Dharwars.

Kurnool.—The Cumbum slates on the western flanks of the low hills of the Velikonda reserved forest, about 2 miles E.S.E. of Janapalacheruvu (15° 28′ 30″ : 79° 9′), show lenses and pockets of manganese ore. According to Mr. M. S. Balasundaram who visited the locality in 1943-44, the slates dip steeply towards E.S.E., and show a lens of ore several feet long and 5-8 ft. thick near the surface decreasing in thickness when followed downwards. It has been worked a few years ago by a trench 200 ft. long, 10 ft. wide and 25 ft. deep. At the N.N.E. end of the trench, two feet of solid ore is seen at the bottom of the trench. A small quantity of ore (psilomelane mainly with some pysolusite) was also stacked near the trench. The prospecting pits nearby are filled up and overgrown with vegetation.

Other districts.—Several small occurrences of pockets and streaks of ore have been observed in the Nilgiri, Madura, Coimbatore, Nellore and other districts but they are insignificant.

Production and Prospects

The Vizagapatam deposits began production in 1892 and have been steadily producing ever since, though the output has shown violent fluctuations from year to year. The Sandur deposits have been exploited since 1905 and have given a large output continuously, except during 1915 to 1920 inclusive. There is also a small

and very irregular production from the Bellary district. The accompanying table gives the available statistics.

Output of Manganese ore in Vizagapatam and Sandur

Year.	Vizag.	Sandur.	Year.	Vizag.	Sandur.
1892	674		1921	16,593	567
1893	3,130		1922	7,845	1,470
1894	11,410		1923	22,524	37,318
1895	15,816		1924	31,811	43,809
1896	56,869		1925	26,909	52,576
1897	74,467		1926	21,698	77,327
1898	62,980		1927	31,992	138,196
1899	84,652		1928	29,094	139,801
1900	92,008		1929	24,533	140,604
1901	76,473		1930	13,213	145,961
1902	68,171		1931	5,389	149,833
1903	63,074		1932	8,049	79,023
1904	53,602		1933	16,698	101,260
1905	63,789	1,200	1934	20,145	127,356
1906	111,501	3,209	1935	15,885	159,436
1907	136,169	23,050	1936	15,258	102,966
1908	94,678	23,413	1937	20,509	149,782
1909	59,818	78,636	1938	31,809	116,574
1910	46,441	73,666	1939	34,640	122,596
1911	58,915	66,950	1940	29,536	46,862
1912	54,758	62,488	1941	14,565	11,470
1913	44,127	52,169	1942	3,065	6,933
1914	26,375	33,643	1943	7,704	3,171
1915	288	—	1944	3,203	653
1916	2,755	—	1945	--	2,158
1917	1,682	—	1946	—	16,415
1918	2,230	—			
1919	2,778	—			
1920	7,386	—			

Output of Manganese-ore in Bellary

Year.	Output tons.	Year.	Output tons.
1907	3,236	1942	18
1912	500	1943	36
1921	2,429	1944	73
1933	300	1945.	—
1935	250	1946	—
1936	100		
1937	450		
1938	2,000		
1939	—		
1940	—		
1941	—		

A production of 200 tons is reported from Kurnool in the year 1937, apparently from the Janapalacheruvu deposit.

The contribution of Vizagapatam and Sandur to the total Indian production (averaging about half a million tons per annum) is appreciable. The bulk of Indian manganese ores, including the entire output of the Madras Presidency and Sandur amounting to a total of 4 million tons to date, is exported out of the country often at a small price. Except for the negligible quantity of potassium permanganate and perhaps a few other chemicals which use manganese-ore as raw material in this Province, no use has been made of the ore. Serious thought should therefore be given to the question of utilisation of these ores in the manufacture of ferro-manganese and chemicals within this country.

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CHAPTER XXXII

MICA

General

The name Mica is applied to a group of minerals having the property of cleaving into extremely thin sheets or laminae which may be thinner than one mil. (0·001 inch). Their specific gravity varies from 2·7 to 3, and the hardness from 2 to 3. All the species are flexible in different degrees, biotite being the least elastic amongst them.

In addition to flexibility, resilience, fine cleavage and heat resistance, the most important property from the commercial point of view is the electrical resistance. The **dielectric strength** (voltage necessary for current to pierce through the sheet of mica) which is measured in kilo-volts per mil. thickness, ranges from 3·3 to 8·5 in muscovite, and from 4·3 to 5·9 in phlogopite. In general, muscovite has a power factor (percentage difference of electrical energy stored in a condenser and that given out after half a cycle) ranging from 0·014 to 8·36 while phlogopite has 0·38 to 7·32. Phlogopite is generally more resistant to heat (up to 1,000° C.) than muscovite (up to 700° C.).

The micas are alumino-silicates of alkalies, alkaline earths and iron, and may contain small quantities of other elements. The different species are:—

Muscovite or potash mica: $H_2K\ Al_3\ (SiO_4)_3$.

Lepidolite or lithia mica: $(OH, F)_2\ K\ Li\ Al_2\ Si_3\ O_{10}$.

Phlogopite or magnesia mica: $H_2K\ Mg_3\ Al(SiO_4)_3$.

Biotite or iron-magnesia mica: $H_2K\ (Mg, Fe)_3\ (Al, Fe)\ (SiO_4)_3$.

Zinnwaldite is a biotite containing some lithium while *roscolite* is a vanadiferous species and *fuchsite* is a green chrome-bearing species. These are not commercially important. Muscovite is the most common mica, being colourless, greenish, reddish (ruby) or silvery. All these varieties are common in Madras, but the greenish ones predominate. Phlogopite is amber-coloured (orangish), the colour ranging from pale yellow to brown and nearly black. It and muscovite are the only two species having high electrical resistance and therefore much sought after. Lepidolite is white, lilac or violetish in colour. It is used as a source of lithium. Biotite is the common black mica with high iron content. In thin flakes it is often green or brown. It is used in industry in the form of powder as a filler as are also all other common micas.

Analysis of Muscovite

—	1 (per cent.)	2 (per cent.)	3 (per cent.)
SiO_2	46·42	46·28	45·57
Al_2O_3	36·77	36·02	36·72
Fe_2O_3	0·21	0·32	0·95
FeO	1·64	1·58	1·28
MgO	0·72	0·84	0·38
CaO	1·28	1·32	0·21
K_2O	8·94	9·10	8·81
Na_2O	0·72	0·82	0·62
Li_3O	—	—	0·19
H_2O	3·24	3·32	5·05
F	Tr.	Tr.	0·19
TOTAL	99·94	99·60	99·93

1. Palamani mine, Nellore (V. S. Swaminathan).
2. Inikurti mine, Nellore (V. S. Swaminathan).
3. Bihar ruby (L. Sipocz).

All micas contain water which generally amounts to 5 per cent. In the variety called *vermiculite,* which is an altered product derived from biotite, the water content may be 10-20 per cent. When heated, phlogopite loses water at 1,000° C., muscovite at 700° C. and biotite at 600° to 650° C.

The perfect cleavage may be interfered with by buckling, ruling, twinning and mineral inclusions. Films and crystals of quartz, feldspar, garnet, kyanite, etc., may be found as inclusions in mica. Sometimes there may be a variation in quality due to difference in composition in the same sheet, which is seen as a natural stain, as opposed to staining by percolating water, decomposition or organic matter. Intergrowths of muscovite and biotite are sometimes seen. Good crystals with excellent crystal faces are occasionally obtained particularly in sizes up to 3 or 4 inches across.

Occurrence

Muscovite and biotite are very common in several types of igneous and metamorphic rocks—granite, diorite, gneisses and schists. Phlogopite occurs in magnesian rocks like crystalline dolomites and

pyroxenites. Workable deposits are, however, confined to pegmatites accompanying granites, diorites and pyroxenites. Pegmatites are rocks of very coarse grain, crystallised from residual liquids containing large amounts of gaseous constituents which induce coarse crystallisation and in which certain of the rarer constituents become concentrated, giving rise to large crystals of minerals like tourmaline, beryl, apatite, monazite, columbite-tantalite, pitchblende, etc.

Pegmatites occur as veins and lenses of various sizes, some lenses being as much as 1,000 ft. long and 200-300 ft. thick. Lenses containing workable mica are generally found traversing mica-schists. The larger lenses generally show a central core of massive quartz surrounded by mixtures of quartz and feldspar and sometimes by feldspar-rich pegmatite. The 'books' of mica (as large crystals are called because of the fact that they can be split into thin sheets similar to the leaves in a book) tend to be concentrated in the feldspathic portion, and especially near the margins of the pegmatite (near the foot-wall, or hanging wall or both). In the smaller pegmatite lenses the mica books may be found everywhere. When 'graphic' structure is developed in the pegmatite (which resembles hieroglyphics) there is generally a lack of workable mica. The muscovite-bearing pegmatites have generally an acid plagioclase (soda-lime feldspar) as the typical feldspar and occasionally some microcline, but orthoclase (potash feldspar) is distinctly rare. This is evidently because much of the potash in the rock has gone into the making of the mica, leaving the feldspar comparatively poor in that constituent.

Uses

The unique combination of the various properties—perfect cleavage, resilience, flexibility, transparency, electrical resistance and heat resistance—makes mica almost indispensable to the electrical industry. Recent developments in high tension engineering would have been impossible without it, for no other mineral or combination of other substances possesses these properties. It is indispensable in condensers and commutator segments used in automobile, aeronautic, electrical transmission, and wireless engineering. It is used in a variety of appliances such as condensers, commutators in dynamos and motors, resistance elements in electrical heating devices, in telephones, spark-plugs, etc. It is used as supports for grids in radio-valves, and as supports for heating elements in lamps. Its other uses are for heat insulation in stove windows, screens, protective spectacles; in fire-proof paints, boiler laggings; as a decorative glistening powder for tiles, wall paper, Christmas trees, etc. Mica may be used in the form of sheets or in the form of micanite which consists of thin films held together by a resinous substance like shellac, glyptal, etc. It is possible to produce any size required in

the form of micanite, as it can be made in large sheets and moulded to shape under heat and pressure. Moulded micanite is used in coils, commutator sleeves, rheostats and transformers. Micanite is generally prepared from splittings (thin films) 0·001 to 0·0001 inch in thickness which are laid flat and brushed over with the adhesive before each layer is laid on until the required thickness is attained. Paper and cloth can also be incorporated in the built-up mica. The material is then pressed under a pressure of 1,000-1,200 lbs. per sq. inch, heat being applied if necessary. It may be moulded to the desired shape during this process. It is then cut and machined. Usually sheet micanite contains less binder than the moulded product, the amount of the binder being 1 to 3 per cent. and occasionally more. Micanite coated with cloth or paper are also made similarly.

For heavy duty spark plugs of aero-engines, the best phlogopite is used because of its higher heat-resistance than muscovite. The material is bonded under pressure.

Ground mica is used in roofing and insulating compositions and in wall paper, rubber, paints, tiles, concrete, etc. For this purpose waste mica is ground. Mica schists are mined and the mica separated and ground for this purpose in the U.S.A.

Mining and Marketing

Workable deposits of mica are confined to pegmatites. Many pegmatites are small and are worked open-cast. Underground mining is done in the larger pegmatites, using machinery for drilling, hoisting and pumping out water. There is much scope for systematising and improving the mining methods in this Province.

Much care has to be taken in drilling and blasting in order to avoid damaging the 'books'. The books are taken out and carried to cutting sheds where they are split and trimmed. The trimming is done by a knife (sickle) or by shears, but the former is preferred as it saves more mica though the shapes are irregular in comparison with the straight-edged shear-trimmed material. In sickle-trimming, the edges are bevelled, which is said to save the mica from fraying out at the edges as often happens when the edges are shear-trimmed. The trimmed sheets are called 'block' mica (or 'sheet'). They are usually ⅛ inch to 1/100 inch in thickness. Condenser films, having a thickness of 0·001 to 0·003 inch are made from the best quality block mica.

Grading is done according to transparency, colour and size. The Bihar 'ruby' mica is considered by the trade superior to the Nellore 'green' but this is in part at least due to the colour prejudice of the buyers. The best quality green is often as good as the best quality ruby in electrical tests. Transparent light coloured mica is of the best quality, the lesser grades being stained and spotted in

various degrees. The quality is often a matter of judgment, but standards have been laid down for correct classification. Nevertheless, the trade has not yet generally adopted rigid tests depending on electrical properties for grading the mica before sale. This is especially the case in India.

The size is determined by the largest rectangle which could be cut from the sheet. Block mica over 5 to 6 sq. inches is generally exported as such while the smaller sizes are split into thin films 0·001 inch or less in thickness. Splitting is done in this country by women and children who have acquired extraordinary skill in performing this operation. Because of the cheapness of labour, some foreign mica (especially from Madagascar and Africa) used to brought to India, split here and exported. Even American automatic machines are said to have been unable to compete with hand-split material, especially as machines were not able to reject unsuitable material in course of the operation.

The following is the description of 'grading' adopted by the mica trade. By its very nature it cannot be made exact and it allows some latitude for individual opinion:—

Superfine.—Hard and optically flat (unbuckled and unstained) block mica; perfectly transparent, without any stains or other flaws.

Clear (Ruby, green or brown).—Optically flat blocks; no bubbles stains or inclusions.

Slightly stained.—Optically flat and hard; no cracks or buckling; no inclusions; slight stains and air bubbles permissible.

Fair stained.—Hard; slight buckling may be allowed, as also a fair amount of stains and gas bubbles; but no inclusions.

Stained.—Hard or soft; slight buckling; no inclusions; Stained and buckled to some extent.

Heavily stained.—Hard or soft; buckled and heavily stained.

Slightly spotted.—Hard or soft; buckled or wavy; spots and inclusions in a small measure.

Heavily spotted.—Same as above; much spotted and with inclusions.

The sizes in vogue in Bihar and Madras are given below. The Madras sizes are used only in Madras for the collection of royalty while the Bihar sizes are those used by the trade in general. It is unfortunate that such an illogical nomenclature, which includes terms like 'Over-Ex-Ex-Special', has become firmly entrenched and the trade is in no mood to change over to a scientific and rational system. It would, however, be desirable for the trade to adopt a system like that of Madras, suitably modified to include the intermediate sizes.

Madras sizes.		Bihar size.	
	Sq. in.		Sq. in.
IX	96-112	Over-ex-ex-special	Over 100
VIII	80-96	Ex-ex-special	80-100
VII	64-80	Ex-special	64-80
VI	48-64	Special	48-64
V	32-48	A 1	36-48
IV	16-32	1	24-36
III	8-16	2	15-24
II	4-8	3	10-15
I.	Below 4	4	6-10
		5	3-6
		5½	2½-3
		6	1-2½

The mainstay of the mica trade seems to be the mica brokers in London, New York and Hamburg. They carry large stocks and are able to fill orders promptly, being located at the chief industrial centres where there is demand for the product. They often reap enormous profits which scarcely ever benefit the producers. Even at the producing end, it is the Sales depots, which are separate organisations buying from the mines and selling to the foreign brokers, who derive more financial benefits than the miners. In recent years some of the larger producers have established their own sales depots and deal direct with overseas consumers. The smaller producers could well be organized into co-operative agencies for the sale of their produce.

India is the chief producer in the world of block mica accounting for about 60 per cent. of the world output. The other producers are Madagascar, Rhodesia, East Africa, Canada, U.S.A., Brazil, Argentine, Bolivia and U.S.S.R. Of these, Brazil and Argentina are likely to come into greater prominence in future.

Much ground mica is produced in the U.S.A.—about 10,000 tons a year valued at over $400,000. There is vast scope in India for the ground mica industry which can utilise all the mine waste now-a-days thrown on the dumps. Both dry and wet grinding are practised, the former yielding a better product as regards lustre. The product is 250 to 400 mesh in size and is used in a number of industries.

Production of Mica in India

(in Cwt.)

—	1937	1938	1939	1940	1941
Bihar	85,978	84,234	85,662	84,270	128,954
Nellore	15,647	22,201	22.429	19,975	14,910
Travancore	67	240	221	170	150
Nilgiris	120	76	108	129	16
Salem	—	638	112	6,412	2
Rajputana	2,814	14,899	28,361	37,413	141,525
Mysore	20	600	1,758	1,546	1,14[illegible]
Eastern States	—	—	1,103	—	—
Gwalior	12	280	—	380	90
Bengal	—	—	15	11	—
Central Provinces	—	—	—	1	—
TOTAL	104,658	123,169	139,758	150,349	286,827

—	1942	1943	1944	1945	1946
Bihar	121,774	103,468	100,299	84,812	91,429
Nellore	18,136	19,858	11,670	14,633	14,123
Travancore	112	100	—	2,560	62
Nilgiris	95	171	67	122	81
Salem	—	66	116	—	—
Rajputana	44,359	34,973	26,610	25,720	7,494
Mysore	746	177	71	9	—
Eastern States	—	399	243	330	158
Gwalior	64	264	240	92	128
Bengal	—	—	—	—	—
Central Provinces	—	—	—	—	—
TOTAL	185,286	159,476	139,316	128,278	113,475

There has also been a small production in recent years from the Coimbatore, Kistna, West Godavari and Vizagapatam districts.

Distribution

Workable deposits of mica are known in several districts : Vizagapatam, West Godavari, Kistna, Nellore, Trichinopoly, Salem, Coimbatore, Nilgiri and Tinnevelly. Of these the Nellore occurrences are by far the most important.

Mica mining in Nellore started as far back as 1887 when mining rights in the Podalakur and Utukur areas were first auctioned by Government. In 1890, Mr. Ansur Subba Naidu, who is said to have made fabulous profits in mica mining later, secured leases in Chaganam, Utukur and Saidapuram areas. The number of leases rose to 70 in 1898 and are now in the neighbourhood of 250, but nearly half of the areas under lease are not actively worked. Only a small number of mines are working in other districts.

VIZAGAPATAM

Phlogopite mica is found at Kudia (18° 7′ : 82° 4′) and Majigudem (18° 12′ : 82° 54′) in the Madugula Estate. Kudia is a small hamlet 12 miles from Devarapalle which is 16 miles by road from Kottavalsa railway station, while Majigudem is 8 miles north-east of Kudia across the hills.

The rocks in these localities are khondalites, granitic gneisses, calc-gneisses and quartzites, associated with charnockites. Phlogopite occurs in pockets in pyroxenites which are intimately associated with charnockites. The mica, which is up to 18 inches across, is often buckled and cracked but contains marketable material also. Four localities near Kudia were prospected. A trench south of Kudia 30 ft. × 9 ft. × 8 ft. gave about 1 ton of crude mica of different sizes. In a *nala* bed 1½ furlongs S.S.E. of the hamlet, a trench 130 ft. long was put down which revealed 9 pockets whose total yield was 3 tons of crude mica. The two other localities, which were 3 furlongs S.W. and S.S.W. of Kudia, also gave mica of smaller sizes. A small quantity may also be available from indications which are present south-east of the hamlet.

Silvery amber mica was found in a field north-east of Majigudem. A trench in the charnockite yielded sheets up to 12 inches across. Other occurrences in the neighbourhood, 300 yards N.N.W., half a mile south and half a mile E.N.E. of Majigudem, yielded pieces 3 to 4 inches across.

Some phlogopite was also got south of Masigudem (18° 12′: 82° 53′); on the S.S.W. slope of hill ·3637 north-east of Mandragudem (18° 10′ : 82° 54′), as well as further up the hill, the mica in all these being up to 4 inches across.

Phlogopite occurs also in an area of 1 sq. mile near Kothiguda west of Borra (18° 17′: 83° 3′) along the Gosthani river. Books up to 18 inches across have been obtained and the deposits require detailed examination.

Good muscovite (white and greenish) occurs in the Chintaladani Metta and Bodi Konda in the Kurupam Estate, according to Prof. C. Mahadevan. The mica is up to 10 or 12 inches across.

Pockets containing muscovite (light ruby) 5 to 6 in. across, were met with in quarrying operations on the hillock just north of the distillery (17° 44′ : 83° 16′ 30″) near Waltair, near mile 4 on the Vizagapatam-Pendurti road. In other pegmatites on this hill only very small sized mica was noticed.

WEST GODAVARI

Small, unimportant occurrences were noticed in the Polavaram agency at the following places :—

(*a*) A few lenses of pegmatite were located at about 1¼ mile up the tributary stream (tributary of Mani vagu joining it north-east of Bothapagudem) from the intersection of the stream and the forest fire line, south-east of Ankanagudem (17° 18′ : 81° 14′ 30″). One of these showed mica 3 to 4 inches across, the others being barren or containing a little biotite.

(*b*) Pegmatite containing poor mica was noticed about 1½ miles S.E. of Ankanagudem, 2 furlongs from the intersection of a stream and the forest line. There are other pegmatites in the neighbourhood, but they show no good muscovite.

Four or five shallow mines were worked for mica about 5 or 6 furlongs north of Kovvurupadu village (17° 11′ : 81° 32′) between 1917 and 1924. The largest quarry is said to be 40 ft. deep. Pegmatite lenses here are up to 20 ft. wide and are said to have yielded good muscovite 9 or 10 inches across. Though the quarries were all filled with water at the time of visit of the writer in 1941, the prospects of obtaining more mica are said to be good, according to local information. It is learnt that these mines may be reopened shortly (in 1948).

In the high ground called Dhanimetta, 6 furlongs south of Nandigudem (17° 9′ 30″ : 81° 30′) there are four old pits which were opened up for mica. Some mica was got in 1932 (6 to 7 inches across in size) during the few months when the pits were worked.

Half a mile south of Pochavaram (17° 9′ : 81° 39′), a few miles north of Kovvur, there are 2 pits, 300 ft.×30 ft. and 15 ft.×15 ft., which were worked for mica some years ago and then abandoned.

They were reopened during the war and yielded some good quality ruby mica up to 10 or 12 inches across, and are presumably being worked at present.

KISTNA

The presence of muscovite-bearing pegmatite has been reported at a locality 3 miles south of Nadigudem in the Mulagala Estate on the Jaggayapet-Suryapet road.

Within the last few years two mines have been worked in the Tiruvur taluk. One of them is in a valley 2 miles west of mile 29 on the Bezwada-Tiruvur road and a little E.S.E. of Jammalavoidurgam (.1848—16° 57′ 30″: 80° 35′ 30″). The pegmatite has been opened up at the surface (50 ft. × 50 ft.) and worked down an incline to 40 ft. depth. Light green mica was got, up to 4 inches across.

There are 2 pits just west of the same road at mile 39/3 close to Lakshmipur village (3 miles south of Tiruvur). These yield light ruby spotted mica up to 8 or 9 inches across.

There are several good indications of mica-bearing pegmatites just west and S.W. of Tiruvur (17° 7′: 80° 37′), near Kammarkuntla (16° 51′: 80° 40′), Gollamandla (16° 59′: 80° 40′ 30″) and south and south-west of Gampalagudem (17° 0′: 80° 31′ 30″) and Gosavidu nearby. Detailed prospecting in this taluk should reveal several useful mica deposits, judging from surface indications of the presence of both ruby and green mica.

NELLORE

This district is composed largely of gneissic and schistose rocks traversed by granites and pegmatites. The schists include micaceous, chloritic, hornblendic and talcose varieties, in the first of which garnet, staurolite and kyanite are developed in some places. The region of abundant pegmatites is known as the 'mica belt' which contains most of the workable mica deposits. This mica belt is V-shaped, the angle of the V being in the south at Vojili (south of Gudur), one arm passing northward towards Nellore, and the other north-west through Saidapuram and Udayagiri. The area covered by the mica belt is roughly 60 miles long (N.N.W.-S.S.E.) and 15 miles wide.

The general foliation direction of the schists is N.W.-S.E. to N.N.E.-S.S.W. (average N.-S.). The pegmatites generally follow the strike of the enclosing schists though usually lens-like in shape. The lenses are frequently arranged *en-echelon.* The pegmatites are composed of quartz and white or pink feldspar. Acid plagioclase and perthitic microcline are the common feldspars. In some places—L. N., Kubera and a few other mines—a beautiful green perthitic microline (amazonstone) is found in some quantity. The larger pegmatites show a central core of massive quartz.

The mica is generally of a light greenish colour, but colourless, silvery and light ruby varieties also occur. The last is got from the Kalichedu group of mines where a pale brown variety also occurs. Biotite is obtained from some pegmatites but it has so far not been utilised, as there is no mica grinding industry in India.

Fairly detailed descriptions of the pegmatites of Nellore are given in a report by Dr. B. C. Roy which has been published by the Madras Government (Development Department G.O. No. 4477 of 20th October 1944) and to which reference may be made for fuller information.

Voduru (14° 4′: 79° 52′)—*Patheregunta* (14° 3′: 79° 54′).—In this area there are a few small properties, the best known being the Krishna Vinodini mine (K.V.D.) situated close to the Madras-Nellore trunk road at mile 75½. The pegmatite here is more than 250 ft. long and yields greenish mica.

Chennur (14° 9′ 30″: 79° 48′)—*Mangalapur* (14° 7′ 30″: 79° 47′ 30″).—The Kandali, Kubera, Varalakshmi, Srinivasa and Venkatalakshmi mines are the best known. The *Kandali* mine comprises 3 pits which formerly produced 50 lbs. of dressed mica per day. The *Kubera* is worked off and on, producing 200 lbs. per day and having reached a depth of 400 ft. The *Varalakshmi* mine is on a pegmatite which is more than 300 ft. long.

Turpupundla (14° 12′: 79° 47′ 30″).—Near this is the Nandalagunta mine in which the pegmatite is over 300 ft. long and mining has been carried down to 200 ft. depth. The *Srinivasa Karuppan* mine consists of two adjoining pits. *Sri Venkateswara* mine is an opencast, 70 ft. deep and quite promising.

Saidapuram (14° 10′ 30″: 79° 44′ 30″).—Several important mines are located in this neighbourhood. *Pallimitta* is an opencast measuring 150 ft. × 75 ft. continued below by underground workings. The pegmatite is over 200 ft. long and produced over 700 lbs. of dressed mica per day at one time. The *Shah* mine is the deepest mine in the district, having reached a depth of more than 500 ft. vertical. It has given a good output of green spotted mica steadily over a number of years. The pegmatite is composite, with schist intercalations, having an aggregate thickness of nearly 200 ft. in places. The average output is 150 lbs. of trimmed mica per day. The *Killy* (or *Ramachandra*) mine is situated on a large pegmatite which is 100 ft. thick at its maximum. During its best days it produced 50 lbs. of dressed mica. It contains some beryl. The Vasantakalyani mine, 2½ miles N.W. of Saidapuram is an opencast 60 ft. deep. It produced 50 lbs. per day and is still likely to give a good output.

Jogipalle (14° 13′: 79° 44′ 30″).—The best known mine in this group is *Chukka Jayalakshmi* (Chukka means spotted) which is on a pegmatite 250 ft long and 100 ft. wide. The mine has reached a depth of 200 ft. The *Nataraja* mine is a large opencast (250 ft. × 75 ft.)

which extends down into underground workings to a depth of 200 ft. Other mines here are *Chintamanigani, Rama Vilas, Panduranga, Prasanna Anjaneya* and *Prasanna Venkateswara* (*Siddalaya*).

Chaganam (14° 12′ 30″ : 79° 41′) is another important centre. The famous *Lakshminarayana* mine (L.N.) is over 250 ft. long in the opencast, and underground workings extend to a depth of 100 ft. Green microcline and beryl are common in this mine. During its best days it produced 400-500 lbs. of cut mica per day and occasionally up to 700 lbs. It has not been worked for some years though it holds good promise. The *Palamani* mine is on a pegmatite 100 ft. long and 50 ft. wide and is a steady producer. The *Nityakalyani* mine near the hamlet of Jafalapuram shows an opencast 150 ft. × 50 ft. with underground workings extending to a depth of 400 ft. This yields about 100 lbs. of trimmed mica per day.

Tellabodu, one of the most famous old mines in the district has been worked since the earliest days (1890's) and is more than 150 ft. deep. At one time it produced 2500 lbs. of trimmed mica per day and over 1000 lbs. per day over a period of 10 years. It has been partly reconditioned and is still quite promising. The other mines in the area are *Chandragani, Balakalyani, Dora, Rama Vilas* and *Nityananda Kalyani*.

Utukur (14° 14′ : 79° 44′ 30″)—*Griddalur* (14° 16′ : 79° 47′).—Amongst the mines here are the *Muniria Vilas, Kasi Visvanatha, Prasanna Sidheswara, Minakshisundaram, Dhanalakshmi, Ramana Mahavilasa, Ramalingaswami, Siddheswara, Pokkandala, Saibaba* and *Sankara*. The last is about the most famous, being situated on a pegmatite 200 ft. long and 100 ft. across, which has been worked to a depth of 150 ft. It yielded 600-700 lbs. of trimmed mica per day in 1907-08 and over 200 lbs. for several subsequent years. It has yielded several hundredweights of samarskite and contains some other rare minerals also. Though it has not been worked for some years it is said to hold good reserves.

Tummalatalupur (14° 17′ 30″ : 79° 42′).—There are several good properties near here though most of them are not working. The *Satyanarayana* mine is an opencast measuring 300 ft. × 50 ft. and producing 200 lbs. of trimmed mica per day though formerly it produced more. The *Bhavanisankar* mine comprises two opencasts located on one pegmatite. The *Sitaramanjaneya Lakshminarayana* mine is located on a pegmatite more than 400 ft. long and 50 ft. wide. It had an output of 100 lbs. of trimmed mica per day in 1939. The *Sudarsano Rama* mine is said to be working an extension of the pegmatite of the above-mentioned mine. It has reached a depth of 150 ft. and contains green microline and beryl. It produced 200 lbs. of cut mica per day formerly and is considered to hold promise. The *Baladurga* is also a promising mine, producing 100-150 lbs. per day. The *Kodandarama*

mine is a large opencast which produced 150 lbs. per day between 1912 and 1925 and a large quantity between 1926 and 1930. The *Umamaheswara* consists of three adjoining pits which together produce 100 lbs. per day. The workings are shallow but are quite promising. The *Venkata-Kanakadurga*, on a pegmatite measuring 300 ft. long and 20 ft. across, has been worked to a depth of 100 ft., producing 100 lbs. per day. It was formerly connected with the *E-mine* which formerly produced well but has been closed down. Nearby is the F-mine which has an opencast 300 ft. × 150 ft. connected with underground workings which are said to be 100 ft. deep. It was a good producer formerly but is not being worked at present. The *Jayalakshmi* mine (Talupur), adjoining the F-mine, is a good property with underground workings extending to 150 ft. depth. In its best days (1917-20) it produced 150 lbs. per day and is potentially important. Some of the smaller mines in this vicinity are the *Bhadrachala Rama, Vijayalakshmi, Veeranarayana, Mahalakshmi, Lakshmi Prasanna* and *Nityananda.*

Kalichedu (14° 18′ : 79° 44′) is perhaps the most important mica mining centre in this district as it gives the largest and most steady output of fine and superfine qualities of mica. There are two parallel sets of pegmatites here, trending N.-S. and separated by a mile width of barren schists. The eastern set can be traced for a length of 2 miles and it may possibly extend further to the north under cover of soil. The western set is of the same length but not so important. Near the southern end, in the Turimerla forest, the mica assumes the usual greenish tint instead of the pale ruby characteristic of the Kalichedu area. The *Kalyanarama* and *Sitarama* mines in this area are said to have produced some sheets measuring 5 ft. by 3 ft. and numerous huge books of smaller size, 2 to 3 ft. across.

The main producing zone is 40 ft. thick and is rich in mica. The *North Tunnels* extend to a depth of 70 ft. and connect southward with the *Kalyanarama* mine which is an opencast (200 ft. × 100 ft.) with underground workings going down to 100 ft. depth. In this the pegmatite is exposed for a length of over 200 ft. The pegmatite is continued S.S.E.-ward into an opencast called *Nilgiri north* and into the *Old Sitarama* mine for a length of nearly 2 furlongs. The pegmatite is rich throughout this length in muscovite, accompanied here and there by some biotite.

West of this vein there is another which is also worked. On this are situated the *Kothokonda* and *Madiga Inam* mines. The latter is an opencast (200 ft. × 100 ft.) with underground workings going down to a depth of 200 ft. Some biotite is found in this mine and in an adjacent opencast. The Kalyanarama group formerly produced as much as 2500 lbs. per day but the present output is around 500 lbs.

The *Sitarama* mine is located to the south of the Kalyanarama group. The old mine consists of an opencast with ground workings extending to 100 ft. depth. The output was formerly 150-200 lbs. per day. The *New Sitarama* mine consists of 2 pits connected by underground workings yielding 150 lbs. of trimmed mica and 100-150 lbs. of 'rounds' per day.

The *Subbarayudu* mine, lying to the south of the Sitarama, has an opencast (125 ft. × 75 ft.) connected with underground workings. This yielded 100 lbs. per day formerly but is not worked now. The *Pattabhirama* mine is further south with an opencast measuring 300 ft. × 75 ft. going down into undergound workings. It produced 100 lbs. of trimmed mica per day but is also in an abandoned state now. The *Bushire* mine, a little further south, has a large opencast (400 ft. × 75 ft.) with underground workings. The southern part of this is called the *Radhakrishna.* These produce 50 lbs. of dressed mica per day but can produce more.

Degapudi (14° 19′ 30″ : 79° 43′).—*Vadlapudi* (14° 18′ 30″ : 79° 48′).—There are a few small quarries in this neighbourhood but they are not important.

Inikurti (14° 20′ 30″ : 79° 43′).—There are several scattered mines here, on either side of the Podalakur-Rapur road. Those to the west of the road yield green mica while those to the east yield honey coloured or light brown mica. *D-mine* in this area is one of the well-known old mines. It is a large open cast (400 ft. × 200 ft.) with underground workings leading down to a depth of 300 ft. The pegmatite exposed in the opencast is 250 ft. long and 50-100 ft. wide. It is said to have produced 600-700 lbs. of dressed mica per day over a period of several years, with a maximum output at one time of 2000 lbs. East of the road there are a few small mines giving a small output.

Marupur (14° 24′ : 79° 48′).—This village lies a little to the north of the 13th milestone on the Nellore-Podalakur road. There are several important pegmatites here but most of the mines are now in an abandoned condition. *Rocklands* (or *Rajarajeswari*) mine which is 3 miles to the north-west of the village has an opencast (400 ft. × 150 ft.) leading into underground workings 100 ft. deep. It produced at one time good quality green mica of large sizes averaging 50 lbs. per day. Some pegmatites to the south of this mine are apparently worth development. North of the above are the *Varadaraja* mines on a series of parallel pegmatites each 15-20 ft. thick. There are two large pits here each measuring 100 ft. × 50 ft. which are said to have given good output formerly. The *Newlands* mine comprises some opencasts the largest of which (300 ft. × 100 ft.) is reported to have yielded 50 lbs. per day. The *Kodandarama* mine near Parlapalle was a small producer and the pegmatite contained some samarskite. A few other small mines also exist in this area.

The pegmatites continue to the north and north-west past Toderu (14° 24′ 30″ : 79° 46′), Kanuparti (14° 25′ 30″ : 79° 41′ 30″), Tatiparti (14° 24′ 30″ : 79° 46′), Kanuparti (14° 25′ 30″ : 79° 41′ 30″), Tatiparti (14° 34′ : 79° 44′), Vasili (14° 37′ : 79° 40′ 30″), Srikolanu (14° 40′ : 79° 47′), Dundigam (14° 42′ : 79° 48′ 30″), Chinna kraka (14° 51′ : 79° 51′) and Gudavalluru (15° 0′ : 79° 41′). There are numerous small mines in this region which give an appreciable output in the aggregate. The better known mines amongst these are Sitaraghava near Surayapalem; Balarama near Battulapalle; Venugopala Krishna near Nallapalem; Veerabhoga Vasantraya, Gowrisankar, Rustum, Prince, Satyanarayana and Chamundeswari near Tatiparti; Parvati Parameswara, Uluvarapalle, Mastan and Yasodhara near Prabhagiripatnam (14° 27′ 30″ : 79° 45′). Several small opencasts and a few underground workings are also noticed near Lakshmipuram (14° 47′ 30″ : 79° 48′), Gudladona (14° 45′ 30″ : 79° 46′), Kommarakonduru (14° 51′ : 79° 49′), Kakaturu (14° 52′ : 79° 46′), Timmasamudram (14° 54′ : 79° 47′), near miles 13½ and 14 on the Kaligiri road Narayanapuram (14° 59′ : 79° 50′ 30″), Narasapuram (14° 59′30″ : 79° 51′), Sripuram (14° 56′ 30″ : 79° 58′), Tallur (15° 23′ : 79° 38′) and Boganampadu (15° 18′ 30″ : 79° 42′).

NORTH ARCOT

Pegmatite containing muscovite of smaller sizes is said to occur in Uchimalaikuppam village in the Chengam taluk of this district. The place has not been visited by any geologist, nor has any sample from the locality been examined.

CHITTOOR

Muscovite is reported to occur near the graveyard of the Union Mission Tuberculosis Sanatorium near Madanapalle. No details are available regarding this occurrence.

TRICHINOPOLY

Dykes and lenses of pegmatite are common amidst the gneisses of Kadavur Zamindari but most of them are barren. Muscovite of the smaller sizes (2-5 inches across) is found in the following places.

A pegmatite 50 ft. long and 20 ft. wide has been opened up by a pit near the *nala* north of Aiyampalaiyam (10° 34′ : 78° 10′ 30″). The pit which is 15 ft. deep, is said to have yielded good quality muscovite. Small books up to 3 inches across can be had here at present.

In a hamlet called Anaikuttitottam, about 1 mile E.S.E. of Idaiyappatti (10° 35′ : 78° 13′ 30″), mica is seen in the debris thrown out of a well. The mica is up to 3 inches across.

There is a pegmatite lens 5 ft. wide on the eastern flank of the hill called Uralchikaradu S.W. of Terku Aiyampalaiyam. The mica is 3 to 4 inches across and pale green.

About half a mile north of Kadavur (10° 35′ 40″ : 78° 11′ 30″) there is an old pit measuring 20 ft. × 20 ft. × 20 ft. in pegmatite which is said to have yielded some mica.

On the north-eastern spur of Mungilmalai, a little below and south-west of peak ·2026, there is a pegmatite exposure 400 ft. long and 50 ft. across. It has been prospected and has yielded some good mica.

The above occurrences were prospected by a firm called the Travancore Mining and Trading Co. in 1920-22. Though they got some saleable mica, it is doubtful whether they made any profit out of their mining. Some of the pegmatites here contain a little beryl and columbite.

Some pegmatites near Manaparai railway station have been worked for quartz and feldspar in recent years but there is no record of any mica having been got in this neighbourhood.

The writer has heard about the occurrence of mica-bearing pegmatites in the Marungapuri Zamindari east of Manaparai and in the adjoining area of Pudukkottai State ; also south and south-west of Karur.

SALEM

Muscovite has been mined intermittently since 1900 from a pegmatite half a mile east of Kurumbapatti (11° 35′ : 77° 52′) which is 3 miles to the east of Idappadi. The pegmatite is over 300 ft. long (N.-S.) and over 60 ft. wide. The mine is now about 60-70 ft. deep. The mica is of light ruby quality up to 6 inches across. A little beryl and columbite-tantalite occur in this pegmatite. There are also a few small prospecting pits for mica, ½ mile W.S.W. of the same village in which mica up to 2½ or 3 inches size is noticed.

Three or four pits, about half a mile north of Karaiyanur (11° 30′ : 77° 56′ 30″) have yielded a little greenish spotted mica during prospecting operations some years ago. The largest pit here is 100 ft. long, 40-50 ft. wide and 15 ft. deep. A small pit near by shows the occurrence of sporadic beryl.

Three furlongs S.E. of Pallippatti (11° 33′ : 77° 55′ 30″) is an old prospecting pit. The mica got here was of small size and not encouraging.

Half a mile N.N.E. of Dasavilakku (11° 38′ : 77° 58′) is an old pit measuring 100 ft. × 35 ft., and 25 ft. deep. It yielded some green mica up to 5 inches across. There is a smaller pit 1 furlong north of this. The northern pit seems to contain some mica still.

Two mile W.S.W. of Idappadi and 1 mile S.W. of Alachchiampalaiyam (11° 35′ : 77° 49′) is an abandoned mine on the northern bank of the Chittar stream. The pegmatite here is over 900 ft. long and of

a maximum thickness of 120 ft. The excavation is 350 ft. long, 100 ft. wide and 70 ft. deep. It was worked for 20 years until World War I, yielding green mica. It is likely to contain more mica. The western continuation of this pegmatite, which contains both muscovite and biotite, has not been opened up.

The Suryamalai, south of Idappadi, contains numerous pegmatites but they are barren of workable mica. Pegmatites are also common in the Tiruchengodu and Namakkal taluks (southern part of Salem) but no workable deposits of mica have yet been located there.

SOUTH KANARA

The occurrence of good muscovite was reported from South Kanara in or about 1921 and sheets 6 to 10 inches across were said to have been exhibited in a district exhibition. G. V. Hobson examined the reported occurrences in 1923. He mentions the following:

Ulamagaru (12° 42′: 75° 15′).—Small flakes in an area some 50 yards east of the Puttur-Sampaja road.

Madnur (12° 38′: 75° 16′) is said to have yielded pieces up to 6 inches across. Much small mica is seen in this area.

Sullia (12° 35′: 75° 25′), Arantod (12° 32′: 75° 27′), Sampaje (12° 30′: 75° 33′), Kalanjia (12° 39′: 75° 24′), Kuthkunja (12° 39′: 75° 29′), Kombar (12° 46′ : 75° 34′) and Bilinile (12° 43′ : 75° 33′)—at all these localities some mica is seen, only Kuthkunja and Kombar giving pieces up to 3 inches across. The mica is generally buckled. There is much soil cover in this area and the pegmatites have not been exposed. No prospecting work seems to have been undertaken here to prove the existence of good mica in the pegmatites which must occur at a few feet depth.

MALABAR

During the War, good quality ruby mica, 10 to 12 inches across, was obtained from pits at *Chovva*, 1½ miles east of Cannanore railway station, and 2 furlongs north of the Cannanore-Tellicherry road. It is not known whether any systematic work was done to open up the deposit.

COIMBATORE

Half a mile S.E. of Vairamangalam (11° 27′ 30″: 77° 37′) which is 4 miles west of Bhavani, there is an opencast measuring 120 ft. × 40 ft. × 25 ft. It has yielded pale green mica up to 12 inches across. A little columbite and beryl also occur in this pegmatite.

Two large pits are seen some two furlongs west of Errappanayakkanpalaiyam (11° 31′: 77° 31′). One of these measures 250 ft. ×

20 ft. × 20ft. They are reported to have yielded good quality green mica 3-4 inches across.

About 8 miles north of Bhavani, near the junction of the Bhavani-Mettur road with the cart track leading to Kurichchi, there are two small prospecting pits which are said to have been put down for mica. The pegmatite here is not promising.

Good muscovite is reported to occur in several places in the Madeswaran malai near Ponnachi (12° 7′:77° 36′). The area is at present difficult of access as it has to be reached from Maddur railway station in Mysore State, though Kollegal and Cowdalli by road.

A property has been opened up in recent years at Punjai Puliyam-patti (11° 21′:77° 10′) about 12 miles from Satyamangalam on the Satyamangalam-Coimbatore road. This has evidently yielded some good muscovite but no details are available.

MADURA

Good deposits of muscovite are reported to occur in Zamindari land near Vattalkundu or Batlagundu (10° 10′:77° 46′). A sample sent by an interested party was found to be of marketable sizes, free from stains but cracked probably due to bad handling.

Muscovite sheets up to 12 inches across are also said to occur in pegmatites at Agamalaipatti near the Periyakulam reservoir. No details are available.

NILGIRI

There are several good deposits of mica in Wainad. The region has a high rainfall and is heavily forested. As a result the zone of weathering is often 20 to 30 ft. deep and prospecting and mining are rendered difficult.

About 400 yards west of the Travellers' Bungalow at Gudalur (11° 30′ 30″:76° 29′) and close to the Gudalur-Nellakota road there is a trench 150 ft. × 15 ft. the dumps near which show the presence of good quality ruby mica. According to local reports the mica recovered was 10-12 inches across.

About 1½ miles N.N.W. of the above and 3 furlongs north of mile 2 on the Gudalur-Devarshola road, a pegmatite lens is seen on the eastern flank of the low ridge in the Salisbury estate. A trench 50 ft. long has been excavated in this which is said to have yielded good ruby mica of 4-6 inches size.

An occurrence is seen on a hillock at Chunduvayal (11° 31′: 76° 26′ 30″) which is about 3 miles due south of Devarshola. Two pits have been put down in an E.-W. trending pegmatite. The mica is light green, rather spotted and stained, and occasionally buckled.

The pegmatite is rich in mica and could yield pieces up to 12 inches across.

Three furlongs N.E. of mile 80 on the Gudalur-Calicut road and just south of the stream flowing past Puliamparai (11° 29′ 45″:76° 26′) there is a pegmatite outcrop which has yielded green mica of sizes up to 14 or 15 inches across. The mica is generally stained and rather spotted. This neighbourhood is quite promising.

Workings in a pegmatite on the western slopes of a hillock to the S.E. of Tambattimalai (·3326) are known as the Amakulam mine. They are about 3 furlongs north of mile 78 on the Gudalur-Calicut road. The pegmatite which runs N.-S. has been opened up in 4 or 5 places revealing a length of 350 ft. and a width of 25 ft. The mica is of ruby quality, slightly stained and spotted and up to 8 inches across. The walls of the pegmatite are richer in mica than the central portions. These workings yielded 3000 lbs. of trimmed mica during a season's working (Nov. 1943—May 1944). Underground mining is difficult because of the soft decomposed nature of the pegmatite. This property deserves further attention. Some pegmatites 2 to 3 furlongs north and east of the above occurrence show good indications of mica.

The Pioneer mines (11° 32′ 45″:76° 20′ 30″) situated 4 miles north of milestone 66¾ on the Gudalur-Calicut road are on a long (N.E.-S.W.) pegmatite ridge dipping steeply to the S.W. The pegmatite has been worked by means of 2 shafts near the north-eastern end from which levels have been driven. Though the mica is sporadically distributed throughout the pegmatite, some concentration is noticed near the foot-wall. There are old workings on the north-western side also. These mines have yielded excellent ruby mica up to 30 inches across, over a period of years but have been temporarily closed down owing to scarcity of labour.

The ridge immediately east of the hamlet of Kolappalli (11° 32′: 76° 20′) consists of pegmatite which is 50 ft. thick. Mica books are concentrated both along the foot wall and hanging wall though some are found in the other portions also. The mica is of ruby colour, partly clear and partly stained and slightly spotted, the maximum dimensions being 10 inches across.

A pegmatite has been opened up at Ulmatam near Ammankaval (11° 21′:76° 21′). It has yielded both clear and stained ruby mica up to 6 inches across.

The New Hope mine (11° 32′:76° 18′ 30″) is about 4 miles N.E. of Cherambadi. The pegmatite, which is much weathered, has yielded good mica in the past and still holds good promise.

Near Pullamangalam (11° 32′:76° 17′ 30″) and about 1½ miles north of the Cherambadi toll gate some pegmatites have been opened. They

yield slightly spotted ruby mica up to 6 inches across. There are other pegmatites in the neighbourhood which were being opened up in 1944.

Some good ruby mica was dug up from excavations made when the power line from Singara to Devarshola (11 Kv line) was constructed, near pole No. 41. This has not been followed up as far as I could ascertain. This locality is not far from Pykara (10° 30′ 30″:76° 35′).

TINNEVELLY

Small pegmatite veins in the Singampatti hills carry some light amber mica which appears to have a composition between muscovite and phlogopite. A pegmatite vein on the eastern slopes of peak ·1361 of Varkamparai showed some good mica up to 6 inches across but the vein disappeared when followed down.

A few other occurrences were met with near the northern foot of the same hill, about a mile south of Kila Singampatti (88° 40′:77° 26′ 30″)—One vein here, 15 ft. long and 1½ ft. thick, yielded some books 9 inches across of light amber mica which was partly good and partly stained and ruled.

TRAVANCORE STATE

Phlogopite occurs in an area about 2 miles by 1 mile west of the road at Mangaram, 1 mile S.S.W. of Tiruvankod (8° 14′ 30″:77° 18′) near Neyyoor in South Travancore. The mineral occurs in pyroxenite traversed by pegmatite. The mica occurs as a string of lenses and pockets along and near the contact of the pegmatite and pyroxenite, and sometimes within the pyroxenite. Individual pockets sometimes yield as much as a ton of crude mica. The zone of weathering is thick, 20-30 ft. frequently. The phlogopite is of a rich amber colour, generally clear and occasionally stained. The pyroxenite is a mixture of pyroxene and basic feldspar while the pegmatite contains much soda feldspar, apatite, occasional garnet and tiny pockets of graphite.

A large quarry has been opened up in charnockite, some 5 miles from Trivandrum near the village called Vettiyurkavu. Spangles of mica are noticed in the basic charnockite while the pegmatites traversing them contain books of different sizes. Sheets up to 10 inches across have been got here but the average is 2 to 5 inches across. The mica is of a light amber colour, clear or slightly stained.

A few miles south of Punalur railway station (9° 1′:76° 56′) there is a mine yielding phlogopite. Here also pyroxenites are traversed by pegmatites.

PROSPECTS

There are extensive deposits of mica in the Nellore district, which hold large reserves. Smaller deposits are found in Kistna, W.

Godavari, Trichinopoly, Salem and Coimbatore. Mica mining, as practised in the Nellore district, is capable of much improvement, but this is possible only if the small producers are eliminated. Large units will be able to introduce rational and systematic methods of working.

Marketing is now done by numerous selling agencies who compete with each other. It would be advantageous to have a co-operative marketing agency run by the producers themselves. Such an agency would be able to hold stocks of various grades and supply the consumers direct instead of employing and playing into the hands of the mica brokers who make a large amount of profit at the expense of the Indian producer.

The internal consumption of mica is negligible, as the Electrical industry is not developed in the country. To enable us to consume a large part of our production, effort must be made quickly to establish the manufacture of various types of electric machinery and equipment.

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CHAPTER XXXIII

MINERAL PIGMENTS

The mineral pigments of common occurrence are red and yellow ochre, umber, sienna and red oxide of iron. Occasionally, other coloured materials may also be used such as grey and black slate and shale.

Red pigments are mostly derived from hematite. 'Persian red' is a hematite from the island of Ormuz in the Persian Gulf; it contains 65 to 72 per cent. Fe_2O_3 and has rich red (crimson) colour. 'Spanish red' is a pure hematite containing around 85 per cent. Fe_2O_3 exported from Spain. 'Venetian red', originally derived from Italy, is the term now applied to cheaper grades of red pigments. Very often iron oxide (limonite and hematite) are calcined so as to give a rich and desirable colour. Red ochre is also of common occurrence.

Brown pigments are mostly limonites. These yield a variety of shades when diluted with white pigments. When manganese oxide is also present in the material it is decidedly yellow brown or dark brown. Umber is dark brownish black containing 10 to 23 per cent. MnO_2, 25-47 per cent. Fe_2O_3 and some carbonaceous material. Sienna is also an iron oxide often containing a little manganese, and having a strong brown colour.

Yellow ochre is the most important yellow pigment. It grades into the Sienna pigments, with increasing iron content. Typical ochre is really a clay in which hydrated iron oxide is highly diffused, the colour depending on the degree of diffusion and the amount of iron oxide.

Various natural green pigments are also in use—green earth, green ochre, terra verte, celadon green. These are greenish clays and chloritic rocks the latter often derived from original amphibole and pyroxene bearing rocks.

Black pigments are usually carbon or black oxide of iron, though some raw umbers are nearly black. Carbon black, lamp black, ivory and bone blacks and charcoal black are commonly used.

Other pigments in use are white clay, whiting, talc, gypsum, barite, etc. These are inferior to white lead, lithopone, zinc oxide and titanium oxide which are well known as important paint materials.

Specifications

Mineral pigments are either fine naturally or are ground to minus 300 mesh. Some like Persian red have an average particle size of 0·80 or 0·85 microns.

The colour of pigments is determined by comparison with a known pigment shade or by means of photometers, colorimeters or similar appliances. Tinting strength is also compared similarly with a standard pigment or measured by tintometer. Particle size is determined by means of the microscope, after elimination of the coarser particles by washing (elutriation). Hiding power (opacity), oil absorption and chemical composition are also amongst the specified tests, though the last is of minor importance in comparison with the physical tests.

Since the important colouring medium in ochres and siennas is iron, natural pigments are generally found in association with iron ores, especially those of replacement or sedimentary origin. Diffusion of iron oxide through percolating ground waters gives rise to red and yellow ochres in shales and clays. Laterite cappings also frequently contain good ochres.

Uses

Mineral pigments are used in paints, colour washes, plasters, mortar and cement which are employed for covering floors, walls, roofs and surfaces of metal, wooden or other articles. They also go into the manufacture of linoleum, rubber and in colour fabrics. They impart colour to these materials, and when employed in paints, they produce also opacity. They may be used as mined, or may have to undergo some treatment such as grinding, washing and roasting or calcining, designed to yield a fine-grained, uniform material of a good shade of colour.

Distribution

EAST AND WEST GODAVARI

Kovvur-Rajahmundry area.—The inter-trappean limestone bed is, for a part of its exposure, overlain by a layer of red and green ochre. The material is very fine-grained and of brick-red colour in quarries south of Duddukuru where it is 4 to 5 feet thick and seen continuously over a length of some 170 yards. Similar material forms a thinner bed, about 9 to 18 inches thick, in the Rajahmundry area where it extends intermittently from Kateru for a distance of 2 miles. The lower part of this is red, and the upper light green.

The material breaks up into small irregular angular fragments. When immersed in water, it slowly softens and yields a very soft (non-gritty) and plastic mass. It can be used as colour wash and for making cheap paints as the colour is not very attractive. The bed at Duddukuru will yield 1,000 tons within a depth (along dip direction) of 10 feet while a smaller quantity will be available near Kateru and Kuntamuru. Much material (perhaps 3,000 tons) has

been allowed to go to waste near Duddukuru. It can be recovered as the quarrying of limestone proceeds.

Dwaraka—Tirumala (16° 57′:81° 15′ 30″).—Beds of rather soft limonitic material occur in association with white clays which are being worked here. The limonitic material could be used as a pigment.

GUNTUR

A bed of yellow ochre forms part of the shale formation (probably in the Kurnool System) worked near mile 3/3 on the Durgi road, about 6 miles south-east of Macherla. The deposit should contain many hundred tons of ochre. Beds of hematite schist occur about 1 mile south-east of Basireddipalle (15° 47′: 79° 35′ 30″) in the Darsi taluk. Some of the material can be used as a paint pigment.

CUDDAPAH

Chabali (14° 30′:78° 36′).—Hematite derived from ferruginous sandstones and quartzites is found on the raised ground S.S.E. of this place. A large old pit here has been estimated to contain at least 41,000 tons of hematite of which an appreciable part is soft and can be used as red oxide after preliminary grinding.

Mantapampalle (14° 19′:79° 5′).—The shales which form the country rocks here are veined with ferruginous quartz veins rich in iron which have given rise to hematite. Some of this material can be used as red oxide as it is soft. Similar material occurs also near Erraguntlakota (13° 57′ 30″ : 79° 16′ 30″).

Patches of yellow ochre are noticed in the Vempalle shale beds about 2 miles N.E. of Nandimandalam (14° 26′ : 78° 31′ 30″) and 1½ miles east of Uppalapalle not far away. Large pockets of yellow ochre are seen also in the same shales 1½ miles south-east of Mittamidapalle (14° 25′ 30″ : 78° 44′). These appear to be capable of yielding a fairly good tonnage.

Sidhout (14° 26′:78° 55′).—On the southern flank of hill ·1281, about one mile north-west of Sidhout railway station, yellow ochre was formerly worked.

KURNOOL

Guttupalle (15° 25′ 30″:78° 3′).—Near this village, especially half a mile to its north-west and 1 furlong to the E.N.E., the Pulivendla quartzites which contain much ferruginous matter have given rise to lenses of iron ore. The hematite is rather hard when fresh but becomes soft on exposure to the weather. A few thousand tons of this material may be available. Rangapuram railway station is only 2 miles from this place.

Veldurti (15° 33′:77° 56′).—A fault zone runs from here towards Ramallakota and contains bodies of iron ore (hematite). The ore is soft where it has been weathered and gives rise to purplish red material which can be used as a pigment.

Ramallakota (15° 34′:78° 0′ 30″).—Yellow ochre is found forming bands and pockets associated with white clay in the shales underlying the Pinnacled quartzites 1½ miles north-east of Ramallakota, south-west of Pullagummi (15° 37′ : 78° 2′) and south and south-west of Kistnapuram (15° 35′ 30″ : 78° 2′ 30″). The ochre is derived from the alteration of the shales. Both the white shales and the ochres have been worked in several quarries in this area.

Betamcherla (15° 27′:78° 9′).—On the southern flanks of the hillocks about 3 furlongs S.S.E. of Betamcherla, are exposed purple shales of presumably Jammalamadugu age which have been altered to white and purplish clays and yellow ochre. One of the workings for ochre which is 30 feet deep from the surface is still in good yellow ochre. A part of the deposit contains a deeper yellow material with a shade of brown. There are likely to be a few other deposits in this area.

Ambapuram (15° 23′:78° 5′ 30″).—About 2½ furlongs south of this village, which is 3 miles from Rangapuram railway station, there are quarries in yellow ochre which is intercalated with clays derived from shales below the Paniam Quartzite. The working pits on a low hillock are 30 feet deep from the surface. The ochre has a good yellow colour. The quarries are over a furlong long and the reserves of yellow ochre here are estimated at about 2 million tons.

BELLARY

According to Foote (*Mem. Geol. Surv. Ind.*, p. 205) several types of ochreous earths are available from the Dharwarian formations of this district. The argillaceous schists and clayey traps also yield drab and dull yellow material used locally as colour wash.

A deposit of good red oxide is worked in the copper mountain 2½ miles west of Obalapuram railway station on the Bellary-Rayadrug branch line.

Sandur State.—The phyllites adjoining quartzites are often red enough for use as ochre, and they are so used. Some localities are—1½ furlongs N.E. of Kammadheruvu (15° 1′ : 76° 37′), half a mile S.S.W. of Obalagandi (15° 3′ 30″ : 76° 31′), near Kumaraswami, and 1¼ miles N.N.W. of Ramandrug (15° 7′ 30″ : 76° 27′ 30″).

Two and a half miles S.S.W. of Vadrahalli (15° 14′ : 76° 28′) red oxide is found as a bed of an average thickness of 50 feet at the junction of ferruginous quartzite and underlying phyllite. The bed extends for one mile along the strike. The amount of material

available within a depth of 60 feet will be 1·5 million tons. A total of over 10,000 tons has already been extracted from these deposits during the last two decades.

Two analyses of this material (by R. V. Briggs & Co., Calcutta, kindly made available by the Sandur Government) are given below. The last analysis (C) is that of material from Obalapuram.

—	A	B	C
—	Per cent	Per cent	Per cent
SiO_2	0·67	1·13	8·14
Al_2O_3	0·03	1·14	1·23
Fe_2O_3	97·79	95·90	66·98
FeO	0·45	—	—
MnO	0·04	0·17	—
MgO	0·16	0·10	1·10
CaO	0·16	0·08	11·64
TiO_2	0·04	0·26	—
P_2O_5	0·06	0·01	—
S	0·002	0·004	—
H_2O	0·48	1·02	—

NELLORE

Beds of hematite schist occur about 1 mile south-east of Basireddipalle (15° 47′ : 79° 35′ 30″) in the Darsi taluk. Some of the material can be used as a paint pigment.

NORTH ARCOT

Tachchur (57 P/6—12° 34′ 30″ : 79° 16′ 45″).—Red ochreous earth occurs in an area of 4 furlongs by 3 furlongs, about a mile N.N.W. of this village. This material is seen to extend down to a depth of 8 to 10 feet from the surface. Its colour is a shade of red, tinged with brown or yellowish brown.

Another occurrence of the same type of earth is found on the eastern flank of hollock ·657, about 5 furlongs W.N.W. of Madimangalam Railway Station (57 P/2—12° 35′ 45″ : 79° 11′ 10″). Here the red earth occurs in an area of 4 furlongs by 3 furlongs and extends down to a depth of 4 to 5 feet. It is somewhat brownish.

The colour of the earth found at these places is below par to the standard red ochres, but the material may still be useful.

Analyses of washed material from these two places carried out by the Agricultural Chemist to the Government of Madras are given below:—

—	A	B
SiO_2	48·40	43·20
Al_2O_3	8·04	17·10
Fe_2O_3	29·50	21·80
FeO	0·96	0·88
CaO	1·12	1·94
MgO	0·98	1·10
K_2O	n.d.	n.d.
Na_2O	n.d.	n.d.
Moisture	4·40	5·19
Loss on ignition . . .	6·36	8·97
Total	99·76	100·18

A.—1 mile N.N.W. of Tachchur, Arni Jagir.

B.—5 furlongs W.N.W. of Madimangalam Railway Station, Arni Jagir.

TRICHINOPOLY

Pale yellow ochreous clay is found amidst the Cretaceous clays near Ayinapuram some 3 miles from Karai. The material can be crushed, washed free from grit and used as a colour wash. A few hundred tons of it may be available here.

PUDUKOTTAI STATE

Red and yellow earths are reported to be worked in the Senkirai Reserved Forest 8 miles S. by E. of, and near Arimalam 12 miles south of Pudukottai. Another occurrence is at Tiruvarangulam about 6 miles E. of the same town. The material is rich red but gritty but can be washed to yield a good quality ochre. It is learnt that over 1,000 tons of this material is sent annually to Trichinopoly and Madura from these places.

RAMNAD

Sivaganga.—Yellow shales and red ironstone layers underlie laterite west of Puvali and Pudupatti (9° 48′ 30″: 78° 31′) 3 miles south-east of Sivaganga covering an area of a square mile. Assuming an average thickness of 2 feet, the reserves would be 2·8 million tons. There are also thin beds of comparatively soft ironstone which would serve as red ochre.

MALABAR AND SOUTH KANARA

Small local pockets of red and yellow ochre are found frequently in the Tertiary beds which cover large areas in these districts. It is not known whether deposits of any size have been discovered so far.

OTHER AREAS

The Cuddapah and Kurnool formations contain soft shales and slates in several places which can be ground to fine powder to make cheap grey paints of various shades such as are used to paint railway freight cars, water tanks, etc. These have so far not been used at all to the writer's knowledge. The waste from the slate quarries of Cumbum and Markapur can be utilised in this fashion.

There are also some manganiferous limonite deposits in Sandur State which may yield material similar to umber and sienna if carefully searched.

Prospects

Two very small factories, one at Madras and the other at Bezwada, have been manufacturing some paints during the last few years. It is unfortunate that no efforts have been made by industrialists to establish a large scale paint industry in this Province in spite of the fact that good ochres, red oxide and barite are available here and that the Madras market is not negligible. It is hoped therefore that paint industry of some size will be established at a suitable locality or localities in this Province and will utilise the available raw materials to the fullest extent.

CHAPTER XXXIV

MOLYBDENUM

The chief minerals of molybdenum are molybdenite (the sulphide), wulfenite (lead molybdate), molybdite (iron molybdate) and Powellite (calcium molybdate), but the first it commercially the most important. This mineral is black, flaky and very soft, being greasy to the touch. It resembles graphite from which it differs physically by having a higher specific gravity (4·7), and a more bluish streak. It can be readily distinguished by its giving off sulphurous fumes when heated over a flame, and by the formation of a yellow to brown sodium molybdate when fused with caustic soda.

Uses

The most important use of molybdenum is in the steel industry as an alloying element. Molybdenum produces refinement of grain in steel and gives it hardness and strength at high temperatures. Chrome-molybdenum steels can stand severe stresses in moving parts and springs. It can be substituted for tungsten in certain high-speed tool steels. It imparts also resistance to stain and corrosion in steel compositions. Fine molybdenum wire is used as filament supports in incandescent lamps and in vacuum tubes screens. Molybdenum plates and sheets are used in radio tubes and in electrical furnaces. Sodium and lead molybdate find use in the manufacture of inks, in the dyeing industry and in enamels and glazes.

Distribution

East Godavari.—In 1915, the Geological Survey of India received some specimens of pegmatite containing molybdenite obtained from a well at Kunavaram (17° 34′ : 81° 15′ 30″). The locality was examined by Mr. G. de P. Cotter who expressed the opinion (*Rec. Geol. Surv. Ind.,* XLVII, p. 22, 1916) that the mineral came from a sporadic pocket and that there appeared to be no other deposit in the neighbourhood.

Trichinopoly.—Mr. P. N. Bose reported the occurrence of molybdenite in a report to the Kadavur Zamindary in 1909. Mr. S. Narayanaswami who visited the locality in 1942, states that the presumed molybdenite-bearing schists occur in a well 300 yards S.W. of Molaippatti (10° 41′ 30″ : 78° 12′) near Mettuppatti. The black mineral is disseminated in a band of fine-grained gneiss striking N.W.-S.E. and dipping at 30° to the S.W. which is partly weathered. It was found, on testing, to be graphite. The graphitic band is only 2 to 2½ feet thick and mixed with much clayey matter, and the size

of the deposit does not warrant the working and recovery of the graphite.

Madura.—Flakes of molybdenite occur in an aplitic and pegmatitic rock traversing gneisses east of Karadikuttam in the Retiambadi Mitta west of Palni. Investigation by Mr. E. Vredenburg proved that there are no useful deposits here (*Rec. Geol. Surv. Ind.*, XLVIII, p. 14, 1917).

While examining a small quantity of graphite derived from the East Godavari district in 1935, the writer came across a few flakes of molybdenite in it. Sir K. S. Krishnan also informed the writer that he detected some molybdenite in small consignments of graphite from Ceylon and East Godavari. As the graphite deposits have not been studied in detail, it is not known whether molybdenite occurs in them in any appreciable quantity. So far, however, no useful source of molybdenite has been encountered in the Madras Province.

CHAPTER XXXV

NATURAL GAS

Occurrences of natural hydrocarbon gases are connected either with petroleum deposits or with accumulations of organic matter embedded in present day sediments. In both cases the gases are derived from the original organic matter entombed in the sediments but while the former contain enormous quantities, the latter are restricted in volume.

Distribution

Three or four occurrences of natural gas have come to the notice of the Geological Survey in recent years. In all cases they are in areas of present day river (Deltaic) alluvia and are not in any way indicative of the presence of petroleum.

East Godavari.—An occurrence of gas at Tatipaka (16° 31′:81° 52′), 3½ miles from Razole was met with in a bore-hole put down in the alluvium, for water, in 1940 in the compound of a rice mill. The gas comes from a depth of 70 feet or so and though the drill hole has collapsed, gas continues to escape from it. Another occurrence is also known about 1 mile south of the above.

Kistna.—There is a small gas seepage in the swampy area east of Kona (16° 5′ : 81° 7′), a village 7 miles south of Masulipatam. The gas bubbles through a small depression and is said to have issued continuously for some years. The yield may be about 1 cubic foot every 3 minutes or so. It sometimes ignites spontaneously and burns with a light blue flame.

Tanjore.—A similar occurrence is known at Neypattur (11° 13′: 79° 48′ 30″) about 7 miles east of Shiyali. Two bore-holes were put down here for artesian water in 1914 and both gave off much gas. One of these is a little east of the Tirunagari road in the compound of a rice mill while the other is about 3 furlongs to the west. The former bore-hole was closed and tamped down with clay and sand at that time, but when an ordinary well was constructed at or close to the original site in 1945, gas began to bubble through the water in the well, which it continues to do even now. The gas emanation from this well should be of the order of about 4 cubic feet per minute, as bubbles rise up briskly from a dozen spots in the well.

The average composition of the gas samples collected from Tatipaka and Neyppattur is shown below :—

—	Tatipaka Per cent.	Neyppattur Per cent.
Oxygen	0·9	1·45
Carbon dioxide	6·0	10·1
Carbon monoxide	1·3	0·9
Hydro carbons unsaturated	1·0	0·5
Ditto Saturated	70·4	69·1
Nitrogen	20·4	17·9

The samples are seen to be similar in composition. They are readily ignited and can be used as fuel for heating or for driving gas engines. Though it was recommended that the Department of Industries should help the owners of the rice mills in the two areas to store the gas in suitable tanks and utilise it for driving small gas engines which might serve their purposes, nothing appears to have been done so far.

CHAPTER XXXVI

PHOSPHATES

Phosphorus is one of the more common elements in the earth and practically all rocks contain determinable quantities of the element. Though its importance for plant growth has been recognised for centuries, by experience, it was only about 100 years ago that its role was definitely established.

There are several mineral phosphates—apatite, struvite, wavellite, vivianite, triplite, etc., but apatite is the most common and commercially the most important. Its composition is Ca_4 $(Ca_3F)_2(PO_4)_6$, but hydroxyl and carbon molecules may replace fluorine and calcium partially. Deposits of good crystalline apatite are comparatively rare, the commercially important ones being fine-grained apatite mixed intimately with clay, lime, silica and other substances. Fluorine (or chlorine) is generally present but varies in quantity from deposit to deposit, those of older geological age generally containing more than those which are younger.

Apatite deposits are generally associated with igneous rocks, the fluorine bearing ones with acid rocks and the chlorine-bearing ones with basic rocks. Lenses, veins and disseminations of apatite may also be found in metamorphic rocks. In sedimentary rocks, phosphates forms beds or nodules, these being almost entirely of organic origin. Phosphates may also replace coralline and other limestones. Phosphatic skeletons and shells are not infrequently found embedded in some sedimentary rocks.

Pure fluor-apatite contains 55·2 per cent. CaO, 41·3 per cent. P_2O_5 and 3·7 per cent. fluorine. Commercial material generally contains some iron, alumina, extra lime, etc. Phosphate rock in nature contains anything up to 90 per cent. of calcium phosphate but commercial grades range from 40 to 75 per cent. For manufacturing purposes iron and alumina content is restricted to 2·5 per cent. but this may be 10 per cent. or more if the material is used for direct application to soil.

Uses

A considerable amount of research on the technology and utilisation of phosphate rock has been accomplished in the U.S.A., especially in the laboratories of the Tennassee Valley Authority. Phosphorus and phosphoric acid used to be made formerly in the blast furnace but are now made in the electric furnace. The power consumption, for a ton of P_2O_5 content in the acid so manufactured, amounts to 5,800 K.W.H.

Phosphatic fertilisers are made by fusing the phosphate with or without other materials or by treating it with sulphuric acid. The latter gives super-phosphate which is the standard commercial phosphatic fertiliser.

Powdered phosphate rock may be used as such as a fertiliser but its solubility in soil is very small. The solubility increases appreciably if used in conjunction with organic manure such as green leaves and farmyard manure. A small quantity of raw phosphate is also used mixed with the food of poultry and livestock.

The major use is for the manufacture of super-phosphate, triple-superphosphate, dicalcium phosphate, phosphorus (element), phosphoric anhydride and phosphoric acid. Phosphate is added in small quantities to the blast furnace charge for obtaining certain grades of foundry iron. Phosphorus is a constituent of phosphor-bronze, phosphor-tin and phosphor-copper.

The element phosphorus is used in making the old type of matches, incendiary shells and smoke-screens.

Ortho-phosphoric acid is used in sugar refining, water softening, photography, in the manufacture of hydrogen peroxide, soft drinks and jams, etc. Sodium and calcium phosphates have also extensive industrial applications in the food industries, photography, fermentation, water softening, etc.

Deposits

Trichinopoly.—The presence of calcareous nodules in the Cretaceous strata (Uttattur Stage) of this district was noted by H. F. Blanford in 1860. Dr. H. Warth of the Geological Survey of India, who was at one time Superintendent of the Government museum at Madras, found that these nodules were phosphatic. He also demarcated the area of their occurrence and estimated that the reserves, to a depth of 200 feet, would amount to 7 million tons, on the basis of some trial excavations in the strata (see below).

The phosphatic nodules occur over an area of 11 to 12 square miles. The nodules are light yellow to buff coloured, and are of all shapes, globular, ellipsoidal and irregular. When broken open they show a dark grey to brown interior, traversed by cracks filled with gypsum, celestite or calcium carbonate. They contain from 15 to 25 per cent. P_2O_5, the average being perhaps 18-20 per cent. The rest of the material is clay and calcium carbonate. The calcium phosphate and calcium carbonate are so intimately mixed that it is almost impossible to separate them by tabling or flotation. A recent attempt at flotation by Mr. P. I. A. Narayanan, Metallurgist in the Geological Survey of India, showed that it would not be economical to adopt this process for concentration. Using minus 48-mesh

material containing 54·5 per cent. calcium phosphate the best concentrate obtained analysed only 62·6 per cent. calcium phosphate, the overall recovery being only 40 per cent. and the consumption of reagents high. The presence of calcium sulphate in the flotation pulp was the cause of high consumption of reagents. The results of prospecting carried out by Dr. H. Warth in 1893 (which were confirmed by the writer during his field work in the area in 1939-40) near Uttattur showed that the strata contained between 10 lbs. and 143 lbs. of nodules per 100 cubic feet in shallow pits, with an average of 28 lb. In some deeper excavations (24 feet deep) the yield of nodules was between 27 to 47 lbs. per 100 cubic feet with an average of 38 lbs. Using the lower figure (28 lbs. per 100 cubic feet of strata) the reserves in the nodule-bearing area of 11 to 12 square miles would amount to about 8,000,000 tons to a depth of 200 feet. If we assume an ordinary workable depth of 50 feet only, the reserves would be 2,000,000 tons.

The crushed and ground nodules have been used in the coffee plantations of South India and Ceylon and pronounced not very successful. The Agriculture Department of the Government of Madras tried the ground phosphate in conjunction with green manure in the rice lands of the Cauvery delta in Tanjore district and found that there was an increase of 9 to 13 per cent. in the yield of paddy (rice grains with husk). This is due to the fact that the phosphate mineral (apatite) becomes appreciably soluble in water in the presence of humus acids and nitrogenous material. It has also been stated that the slow solution of the phosphate under the above conditions in the rice lands was an advantage, but the cultivators do not seem to have taken up the use of the ground raw phosphate seriously.

The utilisation of these nodules for the manufacture of superphosphate has been discouraging because it involves an excessive consumption of acid, so that manufacturers prefer to use Egyptian or Moroccan phosphate. The nodules, can however be fused at a temperature of 1,300° to 1,400° C. when much of the fluorine is eliminated and the material becomes easily soluble in soil. It is also reported by Dr. N. Jayaraman that when the crushed nodules are heated with potash feldspar at 1100°-1200° C., the resultant product is a good fertiliser rich both in phosphorus and potash. It would appear therefore that the nodules can be used along the lines indicated above, and also possibly for the manufacture of phosphoric acid.

A few analyses of the phosphatic nodules are given below:

—	1	2	3	4	5
SiO_2	5·28	3·08	5·56	6·70	3·80
Al_2O_3	2·63	2·83	32·46	30·50	1·83
Fe_2O_3 / FeO	3·14	2·53	1·59 / 1·08	0·40 / 1·08	1·87
MnO	—	—	0·04	0·05	—
CaO	45·51	43·30	21·90	20·16	46·27
MgO	0·34	0·96	0·43	0·22	1·04
SrO	—	1·75	—	—	2·97
K_2O	—	tr.	0·27	0·34	—
Na_2O	—	tr·	0·66	0·83	—
P_2O_5	26·05	27·08	21·75	25·16	24·95
SO_3	0·60	3·26	0·62	1·68	3·56
CO_2 / F	7·23 / 4·84	5·63 / 2·65	9·42	7·59	10·04
H_2O (—) / H_2O (+)	1·53 / 2·85	1·37 / 5·02	4·50	5·27	1·32
—	100·00	99·46	100·33	99·99	—

1. From near Uttattur (Anal. A. Voelcker, London, 1892).
2. From near Karai? (Anal. N. Jayaraman, Bangalore).
3. From near Uttattur (Anal. G.S.I. Laboratory, Calcutta).
4. From near Karai (Anal. G.S.I. Laboratory, Calcutta).
5. From near Karai (Anal. M. Roy Chowdhury, Indian Copper Corp., Ghatsila).

South Arcot—Pondicherry.—Dr. H. Warth reported the occurrence of phosphatised shells in a belt of Upper Cretaceous rocks exposed near Valudavur (11° 58′:79° 42′) and passing in a N.N.E.—S.S.W. direction through Tuttipattu and Akasampattu villages. The phosphatised shells could be distinguished, according to him, by their black colour from the non-phosphatic ones. Recent examination of this area by the writer (1941-42) showed that the shells were enclosed in a sandy shale and though abundant contained too little phosphate to be economically workable.

Nellore.—Crystals of apatite are found in the mica-bearing pegmatites of this district. It is doubtful if any regular yield can be expected from this source.

Vizagapatam district.—Apatite is a constituent of the manganese rich hybrid rocks known as kodurites whose alteration has produced the manganese ores worked in a number of places in the northern part of this district. Fermor states that several hundred-weights of green apatite were obtained from the manganese mines at Devada (18° 15′ : 83° 35′). The mines at Garbham (18° 22′ : 83° 28′), Ramabhadrapuram (18° 30′ : 83° 17′) and other places also showed the presence of quantities of apatite. No attempt seems to have been made to recover the apatite.

In the Vizianagaram Estate, Mr. V. S. Sambasiva Iyer has reported the occurrence of a lens-like deposit of apatite on a hill near the village of Sitaramapuram 25 miles N.W. of Vizianagaram close to the road to Kasipatnam (18° 13′ : 83° 7′). The country rock (gneiss) is also said to contain veins of apatite up to 3 feet in thickness. The lens is roughly 40 feet × 30 feet in surface extent and has been estimated to contain 5,000 tons within 30 feet depth. A sample of the apatite gave, on analysis :—

	Per cent.
SiO_2	1·52
CaO	53·73
P_2O_5	40·5
F	3·47
Cl	0·55

Production and Prospects

There has been a small and irregular production of phosphatic nodules in Trichinopoly, as shown in the following table :—

Year	Output tons	Year	Output tons
1930	31	1938	23
1931	109	1939	182
1932	121	1940	117
1933	37	1941	51
1934	59	1942	120
1935	102	1943	462
1936	128	1944	311
1937	166	1945	524
		1946	243

Except for trials of the raw powdered nodules in the coffee plantations, no serious attempt has yet been made to utilise them

industrially. It would appear that the phosphate can be fused or calcined by itself or with potash feldspar to produce a useful fertiliser. Attempts may also be made to manufacture phosphoric acid from them on a limited scale, if possible.

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CHAPTER XXXVII

QUARTZ AND SILICA

Quartz is pure silica (SiO_2) which occurs in great abundance in the earth's crust as crystals belonging to the hexagonal system, as massive material in veins, as grains of various sizes in quartzites, granites and related rocks and as sand which is a product of disintegration of siliceous rocks. The crystals are generally six-sided prisms surmounted by pyramid-like rhombohedral faces. They occur in cavities in rocks where they have grown *in situ*.

The cryptocrystalline form of silica is called chalcedony which is given different names according to colour and other characters :—jasper—ferruginous red and opaque; plasma—bright green; chrysoprase—apple green ; heliotrope or bloodstone—red spots on green base; carnelian—translucent red; agate—banded in different colours; onyx—straight banded agate. Flint is similar but opaque and of dull colours. Hornstone is rather brittle and splintery while lydian stone is dark hard and fairly tough and is used for testing the streak of precious metals by jewellers. Opal is amorphous silica containing some water.

Uses

Well crystallised quartz is used now-a-days in wireless transmission for the control of frequency. For this purpose the material should not be twinned and should be right-handed or left-handed. It should be perfectly transparent and flawless. Methods have been devised for testing pebbles and lumps showing no crystallographic faces.

Quartz or high-purity silica sand is used in the manufacture of silica ware for the laboratory. For the manufacture of glass, silica sand is preferred but crushed quartz may be used. Sharp sand and crushed quartz are used as abrasives. Silica powder finds application as a filler for wood and paints and in scouring soap. Quartz sand is widely used in lime and cement mortar. Pure lumps of quartz are used in certain smelting operations—*e.g.*, copper smelting.

Transparent quartz, both coloured and colourless, finds use as an ornamental material and as semi-precious stone for making cheap jewellery, trinkets, beads, etc.

Distribution

Quartz veins.—The gneissic and schistose rocks occurring in many districts of the Province are traversed by veins of quartz of various sizes, up to 30 or 40 feet thick and 100 feet or more long. The most conspicuous quartz reefs are those of the mica belt in Nellore where the larger pegmatites have a central lens-like core of quartz. Reefs

of quartz are known to occur in Vizagapatam, Godavari, Kistna, Guntur, Bellary, Anantapur, Chittoor, Arcot, Trichinopoly, Salem, Coimbatore, Madura and Tinnevelly. The active mica mines in Nellore are capable of producing several thousand tons of nearly pure quartz per year, as a by-product of mica mining.

Quartzites.—The Archaean, Cuddapah and Kurnool formations contain quartzite beds some of which are of tolerable purity for industrial use. Some of these quartzites can also be used as abrasive stones for grinding and polishing.

Pebbles.—Pebbles of quartz or quartzite occur in some areas of Tertiary and Gondwana sandstone—Cuddalore sandstones in Pudukkottai, Tanjore and South Arcot; Rajahmundry sandstones in East and West Godavari and the Satyavedu sandstones in Chingleput. Though much of the material is rather brittle and stained, some of it may be suitable for use as pebbles in ball mills.

Quartz crystals.—Rock crystals are comparatively rare. They are found occasionally in the Tertiary grits of Vallam (10° 43′ : 79° 4′) and Sengipatti near Tanjore; in cavities in pegmatites and granites in the Nellore, Trichinopoly and Coimbatore districts and occasionally in other districts; rarely in some of the barytes deposits in the Ceded districts; and derived from granitic rocks on the slopes of the Kambakkam hills in the Chingleput district, the crystals being usually quite small (½ inch long); in a locality half a mile south of Siranganur near Taramangalam, Salem district.

Other varieties.—Rose-quartz has been recorded by Fermor as occurring in the manganese quarries at Sadanandapuram (18° 14 : 83° 34′), and Kodur (18° 16′ 30″ : 83° 33′) in the Vizagapatam district. Smoky quartz is sometimes found in the Tertiary grits of Vallam, Tanjore district.

Hayden (*Mem. Geol. Surv. Ind.* XXXIII, Pt. 2, p. 59) has recorded the occurrence of a greenish, somewhat schistose, quartzite in the hill at Bensibetta continuing to Karayanbetta a few miles east of Bailur (11° 49′ : 77° 15′) in the Coimbatore district. It has been quarried in a small hill called Pachaikalware. Similar rock has been noted near Satyamangalam in the same district. The green colour is thought to be due to the presence of the green chrome-mica fuchsite in the rock.

CHAPTER XXXVIII

REFRACTORIES

The term 'refractory' is used to designate material which withstands a temperature of 1,400° C.—1,500° C. without fusing and also resists chemical attack, spalling and abrasion. Many industries which have to do with heating operations necessarily use refractories. Refractories are therefore important in the smelting and fabrication of metals, heating of materials in furnaces, steam and electricity generation, glass and ceramic industries, oil refining and in other miscellaneous industries. In most of these, the refractories play a very important part as on their performance depends a large part of the efficiency and economy of industrial processes.

The chief refractories in general use are fire-clay, silica, alumina, chrome and magnesite. Fused alumina, fused magnesia and mullite (derived from calcined kyanite and sillimanite) form a group which resist a higher temperature, while a special group composed of *zircon, beryllium oxide, thorium oxide, etc., constitutes the super-*refractories.

Refractories are manufactured in various shapes such as bricks, wedges, arches, segmental blocks, rings, glass tank blocks, checker brick, boiler shapes, etc. Crucibles, retorts, glass pots, muffles, laboratory ware, etc., are specialised items made of certain materials only.

Fire-clay is classified according to its temperature resisting and slag resisting quality as first and second quality material. These are used in blast furnaces, open-hearth steel furnaces, boiler settings, etc. Where a better material than first quality fire-clay is required, high alumina clay (bauxite clay) is used in which the alumina content exceeds 50 per cent. and may range up to 80 per cent. The hot zones of rotary and vertical kilns manufacturing cement and lime and the gas ports of open-hearth furnaces require bricks made of 70 per cent. alumina for efficient working.

Siliceous refractories include quartzites and micaceous quartz-schists which are often used as furnace bottoms, roofs and linings. The bottoms of reverberatory furnaces and acid converters for copper and Bessemer steel are often lined with crushed quartz or quartzite. Silica brick has the property of retaining its strength till almost the fusion point is reached.

Magnesite is used in metallurgical furnaces to resist basic slags. Dead-burnt magnesite is used for this purpose, and it may be applied as a sintered product for hearths in steel furnaces or as bricks for lining. Magnesite bricks are used also in lead and copper smelting, rotary kilns for making cement and lime, chemical furnaces, etc.

Chrome bricks are neutral in their behaviour. They were used formerly as a course between the magnesite bottom and silica roof in furnaces, but are now-a-days put to a wider range of uses.

Mullite is produced by calcining andalusite, kyanite or sillimanite. It is a high grade refractory since it softens only at its melting point of around 1,810° C. Mullite refractories are used in the glass industries, in oil refinery, power plants, etc. They have low coefficient of expansion and are resistant to corosion by slags and gases. They are also used in the manufacture of strong porcelain bodies for spark-plugs, electrical porcelain and laboratory ware.

Fused alumina is used in muffles and furnaces of the 'box' type, in the enamelling industry and in laboratories.

Beryllia, zirconia and thoria (all 99 per cent. pure) melt at 2,300° C., 2,600° C. and 3,000° C. respectively. Beryllia is neutral and yields a hard porcelain-like body; zirconia is resistant to chemical action but is sensitive to temperature changes while thoria is similar but is more basic.

Graphite and carbon are practically infusible but begin to vaporise at over 3,000° C. Carbon is usually bonded with other refractory material for moulding into shapes, the usual bonding material being fire-clay and high alumina clay. Pure graphite and electric furnace graphite retain their shape and physical properties at very high temperatures but they are oxidised in contact with air.

Distribution

Fire-clay.—Fire-clay is available in the Tertiary strata of Godavari, South Arcot, Ramnad and in some places in the Cuddapah basin. Kaolin is found in Nellore, Chingleput, South Arcot, Malabar and Travancore. Factories utilising these are functioning at Rajahmundry, Bhimadolu, Nellore, Ranipet, Tiruvallur, Nellikuppam and Kundara.

Silica refractories.—Quartzite and vein quartz are widely distributed in the Archaeans, Cuddapahs and Kurnools. It is not known whether these have been utilised.

Magnesite.—The Chalk hills area near Salem contain the most important deposits but there are several smaller ones in the same district. Inferior magnesite can be used for making certain refractories as also perhaps some of the altered dunite which is invariably associated with the magnesite.

Chromite.—The chromite deposits of Kondapalle are probably more useful for metallurgical than for refractory purposes. The Salem chromite, being high in alumina, is suitable for use as a refractory.

Beryllia, zirconia and thoria have so far not been produced in this Province—or indeed in India—though the raw materials for their production are available.

The ceramic and refractory industry is still not well developed in this Province in spite of the fact that the requisite raw materials are available. It should be realised by the people who are running the existing factories and those who wish to come into this industry that technical control is necessary in order to produce uniform and high grade products and that technically trained people should be in charge of the factory.

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CHAPTER XXXIX

ROAD STONES AND AGGREGATES.

Crushed stones are now largely used for surfacing roads, for making concrete and for ballast on the permanent way for railways. For all these purposes the crushed stone should have much the same properties.

Rocks are classified under three groups—sedimentary, igneous and metamorphic. Of these, the sedimentary rocks are comparatively less desirable than the others, especially as road stones. For instance some hard limestones and sandstones which may be used as concrete aggregate are scarcely satisfactory as road stones.

Physical Properties

Specific gravity.—This is determined as a matter of routine. It is of no particular importance except to point out whether a rock is dense and compact or not.

Structure and texture are important in that features like banding, cleavage, porosity, etc., have a direct bearing on the durability. Extremely fine-grained (glassy) rocks are generally rather brittle and yield sharp fragments with conchoidal fracture. Coarse grained rocks, on the other hand also tend to break along the borders of the larger grains. Hence medium and medium fine-grained rocks are to be preferred.

Banded and cleaved rocks break easily along planes of banding or cleavage. This is accentuated especially if certain bands are rich in soft micaceous minerals or contain numerous large crystals which are liable to break up under impact or load.

Toughness.—Toughness is a very important property in a road stone. The Deval attrition or abrasion test is more or less a combined test for toughness and hardness. Broken stone, about 1 inch in diameter and weighing 5 Kg., is placed in the testing machine which consists of a small steel cylinder mounted on an axis which is placed making an angle of 30° to the axis of rotation. The cylinder is allowed to revolve 10,000 times at the rate of 30-33 r.p.m. At the end of the test, the material is screened over a sieve with ·065 inch openings. The loss (fine material passing through) is expressed as a percentage of the total weight of stone used—this is the measure of the wear of the stone.

The Los Angeles rattler consists of a cylindrical drum 20 inches long and 28 inches diameter mounted on a horizontal axis. Inside it is a 4-inch shelf extending from side to side. The sample to be tested consists of ½ to 2-inch pieces weighing 5 Kg. and it is put in together with 12 cast iron balls weighing also 5 Kg. The drum is rotated 500 times at 30-33 r.p.m. and the material is screened over a

10-mesh screen, from which the percentage of loss is determined. This test is therefore similar to the Deval test.

Crushing and shearing strengths of stones used for these purposes are also determined.

There are no entirely satisfactory tests of soundness, *i.e.*, freshness, of the stone. Visual examination by one familiar with different types of rocks, fresh and weathered, should ordinarily suffice. Since, however, the stones are generally subjected to a petrographic examination, the report of this examination will include remarks about the degree of freshness.

Petrographic Characters

Examination of thin sections of the stone under the microscope gives information about the component minerals, their freshness and inter-relationship.

Igneous and metamorphic rocks are to be preferred to sedimentary rocks for use as road stones. The rocks should be dense and compact, medium grained, fresh, and free from textural weakness such as banding, cracks, frequent veins of soft minerals, etc. Hence the best rocks to use are granites, trap rocks and compact gneisses. Trap rocks—dolerites and basalts—are amongst the best stones to use as road metals, not only because they are hard and tough, but they also tend to bind easily on the road surface, under pressure.

In view of the large road development plans under contemplation at present, it is necessary for the road-makers to learn a few things about road-metal. As mentioned already, the metal should be fresh, medium to medium-fine in grain, and free from planes of weakness (*e.g.*, cleavage in schist and slate, banding in certain mica-gneisses). Only sound rocks of the approved types should be used. Not infrequently one sees quartz and quartzites used on roads; these are about the worst materials as they are brittle, have no binding power, and give rise angular grains and fragments of sand which play havoc on rubber or even iron tyres. Limestone and ordinary sandstone are soft and may be used only for roads supporting a light traffic. Weathered rocks should be avoided, though contractors persist in supplying these because they are easy to quarry and break to size. Hard ferruginous sandstones and ferruginous gravel ('moorum') can be used for surfacing roads which support only light to medium traffic. If these points are borne in mind it should be possible to make and maintain good roads and avoid producing excessively pitted, bumpy and dusty road surfaces.

For aggregates, it is not objectionable to use some of the softer rock types like limestone and sandstone which will bind well with cement. But the rocks should not contain any constituents which are likely to undergo chemical changes or hydrolyse under the new environment. In all cases it is necessary to use fresh, unaltered rocks as these give the best results.

CHAPTER XL

SANDS

Very large quantities of sand are used for making mortar and concrete for building purposes. The specifications for these purposes are elastic, since the sands should be merely clean and without easily decomposable minerals. But sands used for other special purposes should conform to more or less rigid specifications in order to give the best possible service.

Foundry sand

These include sands used for casting metals and for making moulds or forming cores in the cast materials. These sands should contain a certain amount of clay and should bond well and be permeable to gases released during casting. The material ranges from 3 mm. down to clay in size, the sand grains being angular to sub-angular.

Natural sedimentary deposits yield suitable sands of various grades. Some soft sandstones are also suitable for use after crushing. Sands from dunes may be used for core-sands and also for making moulds after mixing them with the requisite amounts of suitable clay.

Glass sand

Sands for making glass should have uniformity in grain size (with only a small latitude) preferably between 20 and 60 mesh, and very high silica content with a minimum of impurities. For optical glass, the total impurities must not exceed one-half per cent. and ferric oxide 0·02 per cent. The iron oxide may range up to 1 per cent. or a little more in case of common bottle-glass. Alumina may range up to 4 per cent. in certain types.

Sands for other uses

Sands are employed for other purposes such as filtering, as an abrasive and for furnaces. Filter sand should be of uniform size and free from material soluble in weak acids so that they could function efficiently in filter-beds. Abrasive sands must be hard and sharp; they are used for cutting, grinding and polishing stone, glass and metals, for sand blasting and making sand paper. Silica-sand with a certain amount of bonding clay is used to line the bottom and walls of open hearth steel furnaces.

Distribution

Deposits of river and sea sands are found in river valleys and along the Coastal tract. Large areas are occupied by sand dunes which should contain some useful sands. These deposits have not been examined except in one or two cases, hence little is known regarding the availability of various grades.

Deposits of glass sand have been worked in the Coastal tract around Tiruvottiyur just north of Madras. They occur as a layer one or two feet thick, beneath the sandy soil at a depth of 4 to 6 feet. It is not known how much area these sands occupy.

A large deposit occurs in the neighbourhood of Chirala (15° 54′: 80° 12′) in the Guntur district. It extends from Bonnerupalem about 3 miles N.E. of Chirala to Pandillapale 6 miles S.W. of Chirala and has a width of about 2 furlongs immediately to the west of the railway. The white sand bed is around 10 feet thick below an overburden of 3 to 8 feet. It is apparently pure enough for making ordinary grades of glass as the grain size is mostly between 30 and 90 mesh and the iron content quite low. The deposit has not yet been fully investigated.

Prospects

There are large stretches of sands especially along the East Coast which should be worth close investigation, as some areas may yield material suitable for glass manufacture and for other purposes.

There has been a small glass-making industry in Madras for nearly four decades, but it has passed through vicissitudes. At present there are two factories but they are not equipped to manufacture special lines or high quality ware. The industry can be further improved and the possibility of manufacture of special lines should be explored.

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CHAPTER XLI

SODA AND POTASH SALTS

Salts of sodium and potassium are of considerable importance in agriculture and industry. The major sources are the ocean and beds of 'rock salt'. Rock salt is mined in the same way as coal. Ocean water is allowed to evaporate in the open by solar heat in order to recover the common salt (NaCl) content. Large inland lakes (*e.g.*, the Dead Sea, Caspian sea and lakes of Tibet, etc.), also yield salts which figure in commerce. In tropical countries there are areas in which the soil becomes covered in the cold dry season by efflorescent salts. These are called in India 'reh', 'usar', 'Sajji mitti', 'Choudu', etc., and are composed mainly of sodium salts—sodium carbonate and bicarbonate, sulphate and chloride. Potassium nitrate is sometimes found as efflorescence in thickly populated areas as a result of bacterial action on nitrogenous matter (organic matter) in the presence of potash, usually in the form of wood ash.

Uses

Soda salts are used for the manufacture of soda-ash and caustic soda which find application in laundries for the washing of clothes, in the manufacture of glass and various other salts such as silicate, bichromate, citrate, acetate, etc. Caustic soda is used in the manufacture of soap, paper, textiles, rayons, dyestuffs, refining of vegetable oils, etc.

Nitre is used chiefly as a constituent of gun-powder and as a source of potash for the manufacture of some other potash salts.

Common Salt

The chief source of sodium chloride in this Province is sea-water. There are numerous 'salt-pans' in the Coastal tract of several districts where sea-water is allowed to spread as a shallow sheet and to evaporate in the sun, leaving a crop of crystallised salt.

A comparatively insignificant source, made use of by poor people, is the saline efflorescence in some areas in the interior. This is not likely to amount to more than a few tons per year.

Reh

Efflorescences of Reh occur in several districts, especially in the drier parts of the Province. Reh forms in areas of low rainfall with low gradients and elevated water table, which are not well drained. The salts accumulated in the soil are drawn up to the surface during the dry period and are deposited as encrustations at the surface. They may represent the sodium carbonate and sulphate content of

the water accumulating in the area or may be formed from sodium chloride by its action on calcium carbonate (lime) with the aid of atmospheric carbon dioxide.

Stretches of *reh*-covered soil occur in the Vinukonda Narasaraopet and Sattanapalle taluks of Guntur, Penukonda and Anantapur taluks of Anantapur, Tiruchengodu and Dharmapuri taluks of Salem, Perambalur and Ariyalur taluks of Trichinopoly and many other regions. The *reh* from a few of the East Coast districts was analysed by Marsden (1923) and by P. T. Ramacharlu (1944), Chemists in the Department of Industry and Commerce, Madras. Amongst Marsden's 30 samples, the total soluble alkali ranged from 0·63 to 5·9 per cent. while one sample from Coconada contained 50·56 per cent. sodium carbonate, 32·96 per cent. sodium chloride and 16·48 per cent. sodium sulphate. The majority of the samples collected by Mr. Ramacharlu showed 6 to 40 per cent. sodium carbonate. The sodium chloride content was only around 1 per cent. in most cases, only 4 showing between 6 and 18 per cent. The range of sodium sulphate was 0·3 to 6·6 per cent., the average being about 1·5 per cent.

Nitre

Nitre is collected as an efflorescence from the soil in and around several villages near Mohanur and Velur in the Cauvery valley in the Salem district. The salt-laden soil is collected and lixiviated and the solution is evaporated to obtain the salt.

Prospects

The areas visited by Mr. Ramacharlu are only a fraction of those in which the existence of saline efflorescences is known. Even the more promising of these have not been utilised. In view of the scattered nature of these occurrences the collection and purification of the reh can be conducted as a cottage industry, particularly since the material can be put to local use. For this purpose it will be necessary to give training to a number of village people in the purification of the reh, and in the manufacture of caustic alkali therefrom.

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CHAPTER XLII

SLATE

Slates are rocks derived from the compaction and restricted metamorphism of fine clay sediments, which have acquired the property of cleaving in thin layers. It represents a stage between shale and schist. During metamorphism the clay is partly or largely converted into very fine-grained sericite or chlorite. The other minerals present are quartz, hematite, carbon, calcite, rutile, pyrite, andalusite, etc. The relative abundance of these leads to the classification of slates as carbonaceous, siliceous, calcareous or ferruginous.

Slates have a wide range of colours from black to grey, greenish, purplish and bluish. The colours may or may not be permanent if exposed to the weather. Pyrite and marcasite (iron sulphide) give rise to brown stains on weathering while calcite, especially in the presence of sulphides tends to dissolve and lead to the disintegration of the slate.

Slates are generally comparatively soft (hardness=3 to 4) and have a relative density of 2·6 to 2·8. They generally show the original bedding, but this will not affect the quality unless the beds have a fairly wide range of composition. Mineral aggregates sometimes form clots or knots which are undesirable. Folds may be present in regions where the slate has been affected by tectonic disturbances.

The presence of joints and the attitude of the dip of the cleavage planes are of great importance in quarrying, as also direction of 'grain'.

Uses

Slates are used extensively for roofing and building and as blackboards, school slates, electrical switchboards, table tops, etc. Pulverised slate is used as a filler while the granulated material can be used for coating roofs and other building surfaces in conjunction with asphalt or similar material. Cleavability, colour, hardness, crushing and transverse strength, weathering qualities and electrical resistance are of importance in choosing slates for particular purposes. Slate used for electrical switch boards must be of uniform fine grain, free from inclusions and poor in carbon and ferro-magnetic minerals.

Distribution

Only one belt of good slates has been found in this Province in the Kurnool and Nellore districts. It was reported on by M. S. Krishnan and M. S. Balasundaram whose papers may be consulted for details.

The slates form part of the Cumbum Stage of the Cuddapah System. They comprise materials of varying quality and colouring

from hard fissile ones to soft clay-slates, with colours ranging from light grey, greenish and bluish grey, to pink and purple. They are intercalated with thin gritty and quartzitic bands. Depending on the joints and cleavage, thin slates as well as slabs and rectangular blocks are available. They are often traversed by veins of quartz and numerous veins can be seen in the Katakampalle area. The general dip of cleavage is towards E. 30° S. at fairly high angles. The strata have been folded but minor folding is not seen. The cleavage often coincides with the bedding plane. The slate belt is underlain, to the north-west, by the Bairenkonda quartzite which passes to the north-west of Markapur and through the Cumbum tank.

The slate belt extends from Chinna Obanayanipalle (15° 33′: 79° 11′) to beyond Anantavaram (15° 47′ : 79° 22′) over a total length of nearly 24 miles with a width of up to 2 miles. More than half the length of this belt, comprising the middle portion, is in the Venkatagiri Zamindari (Nellore district) while the two ends are near Markapur and Cumbum respectively in the Kurnool district.

Cumbum portion.—Good quality slate forms a band passing through hills ·887 and ·702, about a mile east of China Obanayanipalle. It is worked in several shallow quarries. The slates dip at very high angles or vertically. The best quality material is of limited extent, the width of the band being 120 feet. Quarrying is also done at the western foot of hill ·953, one mile S.S.E. of the above village, where an area of 250 yards by 10 yards of good slate has been opened up.

Markapur area.—This part of the slate belt extends from Nasirsahibpalle (15° 38′ : 79° 16′) through Tummalacheruvu (15° 39′ 40″ : 79° 17′ 20″) to Katakampalle (15° 40′ 30″ : 79° 18′) passing to the west of hill ·908 near Markapur railway station. This portion yields good slates from which school slates are manufactured. Extensive quarrying is done near Katakampalle where the individual bands of good quality are only a few feet thick each. The same band is worked 2 furlongs west of hill ·908 in the Venkatagiri Zamindari. Good quality slates occur within the Zamindari area.

North-eastern portion.—This extends from Rayavaram (15° 43′: 79° 18′ 45″) in the south-west to Mallapeta (15° 49′ : 79° 22′ 30″) in the north-east, passing through Madulapalle and Anantavaram. The slates from this area are generally softer than those of Katakampalle and are dull grey or pinkish grey. Good quality, dark coloured slates are got from a place one mile E.N.E. of Nayudipalle (15° 44′: 79° 19′) and from near Peddayachavaram and Madulapalle.

Prospects

The methods of quarrying and of preparation of the slates are still primitive and wasteful. Less than 10 per cent. of the material

quarried emerges as the final marketable product and there is much waste at every stage. The school slates prepared out of these have not attained to the standard of imported foreign slates. The slate belt also produces comparatively soft clay-slates which are locally used for paving and for partitions and fences.

A few of the samples from the Markapur area, tested for their electrical properties, were found to be good and could be used as electrical switch-boards.

The slate belt is fairly extensive. The introduction of proper quarrying methods and careful preparation will greatly minimise the waste and help the industry to attain prosperity.

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CHAPTER XLIII

STEATITE AND TALC

Talc is a hydrous magnesium silicate, with a specific gravity of 2·7 and hardness of 1, being soft and soapy to the touch. It is a product of metamorphism of magnesian rocks, often being found in association with dolomites and ultrabasic (magnesian) igneous rocks. The term talc is applied to the pure mineral which may be white or pale green in colour and found as bladed crystals. Steatite is the fine grained massive material, generally of high purity, while talc-schist and potstone are impure rocks in which talc is the chief constituent.

Uses

Talc is used as a paint material together with other substances. Talc-base paints can be made non-reflecting and have been much used during the War for camouflage. It is used also as filler in cosmetics, paper, rubber, soap and other industries, for making crayons, for foundry facings and rubber moulds, etc. The most important use of high grade steatite is in making special porcelains and refractories. Block steatite, compact and without cracks, inclusions or grit (called 'lava' grade steatite) is made into insulators in radio transmission, radar and electronic equipment, and also as tips in gas burners. For some of these uses die-pressed talc powder has been used during the War. Lava grade steatite is heat-treated and machined to proper shape.

For certain uses, steatite is finely ground to 50—200 mesh size, floated with pine oil to remove impurities and then mixed with fire clay or other suitable refractory material to make special insulators.

Distribution

Bellary.—Foote mentions the following occurrences in the Bellary district (*Mem. Geol. Surv. Ind.*, Vol. XXV, pp. 34, 43, 128). On the southern side of the Narasimha devar hill and the Arsapur hill, greenish and grey potstones occur. In the Uchingidrug, some 7 miles south of the above, as also in the Nilgunda hill and west of the tank at Harappanahalli, there are good bands of potstone which have been used locally as building stone and for making domestic utensils. Much of the material in these bands is coarse, impure and dirty green to grey but some portions are light coloured and comparatively good. A similar outcrop has also been worked at Somalapur 4 miles S.W. of Sandur (½ mile from Kanevihalli or Yeshwantnagar).

Anantapur.—A few thin beds of fairly good quality, 6 inches to 12 inches thick, are found in dolomite at the foot of a hill 1 furlong S.E. of Jangamreddipalle (14° 41′ 30″ : 77° 54′ 30″). Four or five bands of

steatite are seen in a quarry in Vempalle limestone, half a mile north of Karnapudi (14° 45′ 30″ : 77° 51′ 30″). The material here is grey-coloured and occurs in some quantity.

In the Mutssukota reserved forest about 2 miles E. by N. of Julekalava (14° 50′: 77° 48′) there are a few bands of excellent steatite in siliceous magnesian limestone. The main band, which is 12 to 18 inches thick, is worked by the pillar and stall method at a depth of some 40 to 50 feet. Much of the material recovered from this seam is 'lava' grade, compact and of pale green colour and has been exported to America. A few thinner bands are also present. The steatite bands have a very gentle dip eastwards and have been mined for about 200 yards down the dip. There seem to be appreciable reserves in this area. The steatite is worked entirely by manual labour and no explosives are used. The larger lumps are exported as such and material below 3 inch size is powdered and sold.

About 2 miles S.S.E. of Tabjula (14° 54′ : 77° 49′) steatite is worked in 2 or 3 pits. The thickest band is 12-18 inches thick and the quality is good. One of the workings is being continued as an underground mine.

Thin bands of steatite, 4 to 6 inches thick, are worked at a locality 1 mile west of Chandrapalle (15° 13′ : 77° 49′). The material is rather gritty and inferior in quality.

Compact, yellowish to greenish material practically free from grit occurs near Nerijumpalle (Gulumarri) on the hill called Balapapurangi gutta where it is said to be abundant.

Kurnool.—Between Muddavaram and Venkatagiri, near Betamcherla, the Vempalle dolomitic limestones have been converted into steatite in places, along some layers. (See *Mem. Geol. Surv. Ind.*, VIII, p. 166). The material is grey, pale green or white and has been quarried for some years. Mr. A. Ghose worked some of these deposits (Muddavaram, Musilacheruvu and Balapalapalle) between 1912 and 1915. Formerly curios used to be manufactured out of this steatite.

Pale green steatite of good quality occurs at Pendakallu in the Dhone taluk where some 5 quarries were working in 1888. The material occupied an area of some 10 acres and was free from grit and homogeneous and compact.

Vizagapatam.—Potstone has been worked near Ontagaon, 3 miles from Jeypore and used as building stone and for carving. Large masses of steatite and potstone are also seen on the Malkangiri road 5 miles beyond Kolar (18° 42′ : 82° 23′).

Nellore.—Impure talc schist is found in association with phyllites, striking N.N.W.-S.S.E. 1½ miles S.S.W. of Edavalli (15° 28′: 79° 32′ 30″), mainly on the slopes of a small hillock.

A small exposure of impure potstone is worked near the border of Jogipalle Shrotriem not far from the Shaw mine. It is generally gritty and somewhat coarse with abundant inclusions of chloritic and ferruginous matter. Some potstone utensils are made here and sold locally.

Talc schists have been noted in the valley between the two quartzite hills north of mile 47 on the Kanigiri-Vemulpadu road. Similar material has been noticed also in the hills south of the above locality.

Chittoor.—Compact pale green steatite of fairly good quality, traversed by veins of crystalline flakes of talc occurs near Pathur village. Gangadharanallur in the same district is also said to contain good steatite.

Salem.—At the foot of the Isvaramalai hill are a few quarries which formerly yielded steatite. The material was rather gritty and contained inclusions. But when these inclusions and grit were removed the material was very smooth and of good quality.

Potstone has been recorded (*Mem. Geol. Surv. Ind.*, IV, pp. 317, 324) as occurring at Karuppur seven miles N.W. of Salem, at Tandagoundanpalayam 17 miles E.S.E. of Salem and at Yermapatti 35 miles S. by E. of Salem.

Steatite-schist is extensively developed in the area around Chinnappanpatti (11° 36′ : 77° 57′) near Idappadi. It is shaped into domestic utensils.

Extensive deposits occur near Mecheri, Aranganur, Periya Sorragai, Enadi, Nachampatti, Semmandapatti, Idangasalai, etc., in the Omalur taluk. The stone is worked into utensils, idols and toys by the local workers and sent to Salem and other towns for sale. About 200 families are said to be engaged in this work in this area.

There are some occurrences near Virapandi railway station (Ariyanur) and near Makkalpudur north of Namakkal which are also put to similar use.

North Arcot.—Foote mentions (*Rec. Geol. Surv. Ind.*, XII, p. 193) the occurrence of talcose beds near Damarpak north of Arni, at a place 8 miles N.N.W. of Ranipet and west of Ponnaiyar, and at Murtapalle 20 miles north of the above.

Trichinopoly.—Potstone occurs between Musiri (10° 57′ : 78° 27′) and Kannanur. It is used locally for making utensils.

Coimbatore.—Pale green, compact, rather gritty steatite is known to occur in the hills near Edamaranhalli village, Kollegal taluk.

South Kanara.—At Manavalike village, Uppinangadi taluk pale buff steatite showing reddish specks and streaks is found. It is schistose in appearance, fairly free from grit and somewhat hard and compact.

Of all the deposits mentioned above only those in the Mutssukota reserved forest seem to be of the best grade and have been worked for export. Most of the other deposits yield potstone from which carvings, toys and utensils have been shaped for local use. It is not unlikely that some of them contain high grade material suitable for grinding to powder for employment as filler.

Though a fairly numerous population ekes a livelihood from the deposits in the Omalur taluk, Salem district, there is no organised quarrying or working of the potstone, the latter following the same primitive methods as have been in vogue here from time immemorial. The provision of a few simple mechanical aids would conduce to better workmanship and less wastage of material. This is an industry in which the Department of Industries can very well interest itself and render help to the artisans.

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CHAPTER XLIV

STRONTIUM

The two commercially important minerals of the comparatively infrequent element strontium are celestite and strontianite.

Celestite (Sr SO_4) is a pale bluish mineral having a Sp. Gr. of 4·0, and resembling barite and gypsum to some extent. It has about the same hardness as barite and can be distinguished from it by the slightly lower specific gravity and the crimson (strontium) colour it imparts to a flame.

Strontianite (Sr CO_3) is a white, yellow or greenish mineral of columnar habit with a Sp. Gr. of 3·7 and hardness of 3·5. It is easily attacked by dilute mineral acids whereas celestite is not.

Uses

Strontium hydroxide is used in beet-sugar manufacture where, on heating with molasses at about 100° C., it yields strontium di-saccharate. The latter, when treated with carbon-dioxide, precipitates strontium carbonate, leaving a solution of sugar.

Strontium nitrate and carbonate are used in flares, fire-works, signals, military rockets, tracer bullets, etc., to which they impart a vivid crimson colour which can be seen for a long distance. Strontium sulphate is used in paints in the same way as barite in the paint industry, and is said to be superior to the latter both in oil colours and in 'lake' colours. Strontium chromate is a bright yellow pigment. Strontium compounds are also used in ceramics, glass and enamels, in medicines, in refrigeration and in cathode ray tubes.

Distribution

The occurrence of celestite in the Cretaceous strata of the Trichinopoly district was discovered by Dr. H. Warth in 1893 but his report was forgotten as it was hidden away in Government Proceedings. It was rediscovered in 1924 by Mr. Ramaswami Sivan of the Madras Department of Agriculture. Dr. N. Jayaraman and Dr. K. R. Krishnaswami of the Indian Institute of Science. Bangalore, noted its occurrence in the phosphatic nodules from the same strata. The occurrences were investigated in 1939-40 by the present writer and his colleague Mr. N. K. N. Aiyengar.

Celestite occurs sparsely distributed as veins in the clays of the Uttattur Stage of the Cretaceous in the Perambalur taluk, Trichinopoly district. It is fairly common in the neighbourhood of Uttattur (11° 4′ : 78° 51′ 30″), Karai (11° 8′ : 78° 53′) and a few other villages. The veins are up to 4 inches thick being composed of columnar crystal aggregates arranged with their lengths perpendicular to the length of the veins. It is associated with carbonates of calcium

and strontium, gypsum and earthy matter. Some celestite occurs as thin plates filling the cracks of phosphatic nodules (and occasionally as a concentric layer around them) but this source is insignificant compared to the veins. It has been estimated that the area contains between 44,000 and 110,000 tons for every 10 feet depth of strata. If it occurs to a depth of 50 feet from the surface, the total quantity will be of the order of a quarter to half million tons. The quality of the material is generally good, with a strontium sulphate content of 85 to 95 per cent. It is sometimes interbanded or intergrown with layers of barite

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CHAPTER XLV

SULPHUR AND PYRITES

Sulphur occurs in nature in the form of the element (native sulphur), sulphides of several metals and as sulphates. Of these native sulphur and pyrites (FeS_2) are the chief sources of sulphur.

Sulphur is a yellow substance crystallising in the orthorhombic system, having a hardness of 1·5 to 2 and specific gravity of 2·05. It has a resinous lustre and melts at about 115° C. and boils at 445° C. It is insoluble in water and in most of the acids, but is readily soluble in carbon disulphide and carbon tetrachloride. It is easily ignited and burns with a blue flame, giving off sulphur dioxide fumes.

Pyrite ($Fe\ S_2$) is a yellow mineral with metallic lustre, crystallising in the isometric system. Hardness 6 to 6·5 and Sp. Gr. 4·9 to 5·2. It gives a black streak with a greenish tinge. When pure, it contains 53·4 per cent. sulphur.

Marcasite has the same composition and characteristics but crystallises in the orthorhombic system. It generally occurs in crystalline aggregates showing multiple twinning.

Pyrrhotite is another sulphide of iron, with rather varying composition (Fe_nS_{n+1}) and containing about 38 per cent. sulphur. It has a bronzy colour and black streak, but is distinctly magnetic. It crystallises in the hexagonal system. Hardness about 4 and Sp. Gr. 4·5 to 4·6.

Sulphides of copper, lead, zinc, etc., are sought after more for their metallic content and are not considered sources of sulphur.

Native sulphur is found in sedimentary deposits and in volcanic tuffs. The latter are clearly of volcanic origin while the former may be of volcanic, chemical or bio-chemical origin.

The sulphide minerals are of direct igneous origin or may be hydrothermal, *i.e.*, deposited from waters connected with igneous sources. They occur as masses in igneous rocks and as replacement bodies and veins.

Uses

The most important use of sulphur is for the production of sulphuric acid which has numerous uses in industry. Some of these are: the manufacture of superphosphate, ammonium sulphate, titanium dioxide, explosives, motion picture films, paper, rubber (natural and synthetic), insecticides, pickling of iron before galvanizing and tinning, etc. Sulphuric acid enters into many chemical industries at some stage or other and its production is one of the most important indices of the industrial advancement of a country.

Distribution

NATIVE SULPHUR

Within recent years some deposits of native sulphur were found near Kona (16° 5′ : 81° 7′) about 7 miles from Masulipatam in the *Kistna district. The area is a low-lying coastal tract subject to* inundation by sea-water during the monsoon. There are two small *tracts, 1 mile north and 1 mile south of Kona respectively, where* some sulphur is found in the marine silts formed in recent geological times. The southern patch shows yellow grains of sulphur impregnating the silts to a depth of about 24 inches from the surface. The clay below this smells strongly of hydrogen sulphide. The sulphur-bearing area is about 25 to 30 acres in extent. The sulphur content of the clays varies from 1·6 to 45 per cent. The writer also heard about the existence of one or two other similar deposits in the same district but could get no details.

The area is of deltaic origin and there are no signs of volcanic activity here. It would appear that sulphur has been formed from the gypsum of the sea-water (which periodically soaks the area) by the action of sulphur bacteria. Such organisms have been found in ditch muds, vegetable mold, sewage, canal and coastal silts and sands. S. V. Ganapati found that *Microspira aesturii* was present in the muds of the Buckingham Canal at Madras and also several species of sulphur-reducing bacteria (especially *Vibrio desulphuricans*) in the slow sand filter beds of the Madras Corporation Water Works during the period of drought in 1939-40. Dutta has found similar organisms in the mud of an irrigation canal and in the waste matter in the anærobic fuel gas plant of the Agricultural Research Institute, New Delhi. These organisms were found to reduce sulphates to sulphur at a temperature of 30° C. at an optimum pH of 7·5 to 7·7, giving a recovery of over 6 per cent. sulphur in the experiments.

In my report on the deposits of Kona early in 1944 I recommended that the Government of Madras should arrange for further studies to be undertaken in the laboratory with a view to determine the conditions of formation so that the formation of sulphur could be induced at suitable localities in other coastal tracts. This work was entrusted to the Indian Institute of Science, Bangalore, who have since published some results, but do not seem to have carried the investigation to completion. The tentative conclusions arrived at by the investigators are that the process of sulphur formation is through the agency of *Vibrio desulphuricans* which is most active at a temperature of 30° C. and at a hydrogen-ion concentration of 7·2 to 7·4 and a sulphate concentration of up to 6 per cent.

It is very desirable that this investigation is carried to completion and the possibility of inducing the formation of sulphur in suitable localities studied so that a regular, though small, supply of sulphur can be obtained from such sources periodically.

PYRITE

Pyrite occurs in several places in the province but so far no deposit capable of yielding a large tonnage has been found.

Veins of pyrite are found occassionally traversing the gneissic rocks in a few places in the Salem, Coimbatore, Tinnevelly and other districts. The occurrences are all insignificant.

The calcareous flags ('Cuddapah Slabs') of the Jammalamadugu formation in the Cuddapah and Kurnool districts contain numerous small cubes of pyrite, ordinarily about 5 mm. across. They are fairly abundant along certain bedding planes. It is learnt that these crystals are separated from the slabs and sent to Bombay where there is a demand for them by Ayurvedic physicians for medicinal preparations. The quantity won may amount to perhaps 2 to 5 tons in a year from the various quarries.

The only good source of pyrite in the Province is the gold-bearing pyrite veins of Wainad and Malabar. Many thousand tons of pyrite must be available in the Devala—Pandalur area—*e.g.*, in the Alpha, Nadghani, Harewood, Rosedale and other mines. If gold mining on a systematic basis is revived in this region, it should be possible to recover the pyrite as a by-product of gold and utilise it as a source of sulphur.

PYRRHOTITE

A deposit of pyrrhotite is known to occur in the Thaniar reserved forest, about 3 miles S.W. of the Thaniar forest Rest House (12° 32′ 30″ : 79° 3′), which is about 7 miles west of Polur (12° 31′ : 79° 7′ 30″) in the North Arcot district. The deposits occur at the base of a spur of the Periyamalai. The country rocks are banded biotite and hornblende gneisses, garnetiferous gneisses and charnockites. Some magnetite-quartzites are also seen 1 mile N.W. of the Rest House and on the Karnaticgarh hill. The gneissic banding strikes N.E.--S.W. or N.N.E.--S.S.W.

The sulphide vein traverses the gneisses and charnockites, the mineralised rock containing various proportions of quartz, pyroxene or amplibole, and garnet, besides pyrrhotite. The country rock has been silicified during mineralisation, as evidenced by the presence of a hornfels-like rock accompanying the ore. The lode is of varying width and follows a plane of weakness. The presence of ore is indicated by a crust of limonite and by dirty yellow powdery material.

The deposit was examined by Rao Bahadur M. Vinayak Rao in 1924 and 1927, and sometime later Mr. Geo. Sampson put down a bore-hole in Prospect No. 1 which is a low hillock north of the Periya-malai. A pit put down here showed thin stringers of sulphide in quartz. Prospect No. 2, which is a continuation of the vein in No. 1 is on a low ridge. Some old pits in this were deepened, one of them showing a lode several inches thick, dipping at 60° to the north-east.

There is another occurrence here (Prospect No. 3) 1¼ mile up the Guliar *nala* on the flank of the hill. This shows banded hornfels 1½ to 2 feet thick, containing some specks and stringers of sulphide.

Two specimens collected by Rao Bahadur Vinayak Rao, presumably from Prospect No. 2 gave the following analysis:—

—	1	2
	Per cent.	Per cent.
SiO_2	17·28	19·35
Al_2O_3	8·72	1·66
Fe_2O_3	17·32	19·32
Fe	31·06	21·77
Ni, Mn	Tr	Tr
MgO	1·02	0·94
CaO	0·98	Tr
SO_3	0·91	5·30
S	20·16	25·16
K_2O	0·18	—
Na_2O	1·38	—
H_2O	1·92	3·40

1. Analysis by A. K. Dey, G. S. I. Laboratory.
2. Analysis by V. S. Rajagopalan, G. S. I. Laboratory.

Samples were taken by Mr. R. N. P. Arogyaswamy from prospects 1, 2 and 3 and assayed by him, with the following result:—

Prospect.	Sample No.	Fe	S
		Per cent.	Per cent.
1	23	29·31	18·95
1	25	37·97	23·19
2	19	47·74	28·15
3	28	16·75	14·72
3	46	21·22	15·46
3	47	41·04	24·77

All the samples were tested for arsenic, nickel and copper and gave *nil* result.

In prospect No. 2 a tunnel was made 12 feet long and this showed a continuous lode 3 to 4½ feet thick. The indications are that the lode is nearly 440 yards long. Mr. Arogyaswamy estimates that this prospect contains 17,000 tons of ore within a depth of 30 feet from the surface, with an average content of 25 per cent. sulphur. Prospects Nos. 1 and 3 also contain some ore but data for estimation of reserves are meagre. Messrs. Parry & Co., Ltd., Madras, put down a bore-hole in 1943 to the dip side of the middle portion of prospect No. 2. It was estimated that the drill hole would cut into the lode at a depth of about 85 feet if the dip were 60° and at 110 feet if the dip were 70°. The progress of drilling was slow and it was stopped at a depth of 85 feet without cutting into the lode. There are indications of the presence of a good lode in prospect No. 2 and it should be worth further investigation at a future date.

Prospects

The study of the sulphur formation at Kona, Kistna district, indicates that biochemical activity can be made use of for the production of sulphur under suitable environment. This source, though small, will yield sulphur of high purity.

There are good possibilities of obtaining a large tonnage of pyrite from the gold-bearing lodes in Wainad. These could be exploited for their gold content, yielding pyrite as a useful by-product.

The pyrrhotite deposits of Thaniar (North Arcot) contain a useful tonnage, estimated at 17,000 tons in prospect No. 2 within a depth of 30 feet from the surface. These would form an additional source of sulphur.

India is extremely poor in sources of sulphur which is a valuable material for modern industry Hence every source should be properly investigated and exploited.

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CHAPTER XLVI

TITANIUM

The chief titanium minerals are ilmenite, titaniferous magnetite, rutile, sphene and perovskite. Ilmenite is the most abundant titanium-bearing mineral in the earth's crust. In composition it is an iron titanate ($Fe\ TiO_3$), with black colour and sub-metallic lustre. Its hardness is 5·5-6 and specific gravity 4·5-5·0. It contains 31·6 per cent. titanium and 37·2 per cent. iron. The mineral is found in many igneous and metamorphic rocks, as grains and sometimes as veins. It is won both from primary veins and segregations as also from detrital sands.

Titaniferous magnetite is quite common, and as the name indicates, is a magnetite in which part of the iron is replaced by titanium. The titanium content is usually around 10 per cent., and may occasionally go up to 20 per cent.

Rutile (TiO_2) is a constituent of some igneous and metamorphic rocks. It is red brown or black in colour, with a hardness of about 6·5 and specific gravity of 4·25. The transparent material may be used as a semi-precious stone.

Sphene ($CaTiSiO_5$) and perovskite ($CaTiO_3$) rarely occur in sufficient concentration for economic exploitation.

Uses

Titanium forms alloys with several metals but it is used chiefly in steels to which it imparts resistance to abrasion and shock. It is particularly useful in steels for making sheets and for parts exposed to severe stresses and shocks. Rutile has been used for coating parts to be welded as it promotes good welding.

The most important use is, however, in the manufacture of the pigment called titanium-white. It is bright white, with high opacity, covering power and non-poisonous nature, and is useful for covering surfaces exposed to sea-air, sea-water and corrosive gases like hydrogen sulphide. It can be mixed with other pigments, in different proportions. Titanium dioxide is also used in enamel compositions and in the plastics, ceramics, paper, textile, rubber, ink and other industries. Titanium chloride, when exposed to air, produces dense white fumes, which property is made use of in sky-writing and in producing smoke-screens.

Distribution

RUTILE

Rutile is found in small quantities in the beach sands of Travancore and has been regularly recovered from them in recent years. It has been detected in the sands of the Eastern Coast (Madras

Coast) but these have not been closely enough examined for purposes of estimating the quantities available. The extraordinary demand for rutile during the War for use in arc-welding led to the export of rutile by the companies engaged on working the Coastal sands of Travancore.

The rutile content of the original sands as dug up is only 1 to 2 per cent. After the concentration of ilmenite and monazite by magnetic separators, the tailings contain practically all the rutile and zircon. The rutile content of these tailings may be as much as 30 per cent. These are passed in a thin stream through high voltage electrostatic separators in which rutile grains become deflected from the main stream and get separated. The material is repeatedly passed through the electrostatic separators until the final product contains over 90 per cent. rutile. It is possible to get the concentration to 96 or 97 per cent. rutile. Mr. Viswanathan states that during the past few years the Travancore Minerals Company produced 6,500 tons of rutile. The total production of all the Companies working in Travancore may be estimated as exceeding 10,000 tons.

ILMENITE

The only commercial sources of ilmenite are in the Coastal sands of Travancore, Malabar and some of the districts on the Eastern Coast. where it occurs in association with other heavy minerals like magnetite, garnet, monazite, zircon and rutile. These minerals are concentrated in layers varying in thickness from mere thin streaks to those which are 2 feet. The layers are interbedded with silica sand. Only a narrow strip about a furlong wide along the Coast has been examined but it is known that it is sometimes found concentrated in the sand dunes some distance from the water front.

Some ilmenite is also found in the sands of streams in the interior draining rocks rich in the mineral. So far, no rocks have been found in the Province containing ilmenite as veins or in sufficient concentration in rocks containing it to be considered as a direct source.

Travancore State.—G. H. Tipper has recorded five areas rich in mineral sands, mainly from the point of the availability of monazite. These are: (1) Lipuram to Cape Comorin (East Coast), (2) Muttam—Pudur, (3) Kovilam, (4) Anjengo—Warkalli, (5) Nindakara. The deposits consists of a series of layers usually a few inches thick and up to 100 feet wide from the water front. In some cases (*e.g.*, near Colachel) the sand dunes some distance away from the present beach have been found to contain these minerals in workable concentrations.

The Lipuram deposit extends for some distance on either side of the old fort here. The sands are rich in ilmenite and contain also other minerals. The deposits have not been worked.

The Manavalakkurichi (8° 8′ : 77° 18′) area near Colachel has been worked since 1911 and shows signs of exhaustion, especially of ilmenite. The deposits extended for a mile along the Coast.

The Nindakara deposits are a few miles north of Quilon and extend from Nindakara to the Kayankulam bar, a distance of some 8 miles. This strip is being actively worked at present by three or four firms.

The Travancore deposits contain 70-90 per cent. of heavy minerals but portions are poor. The heavy minerals are derived from the disintegration of charnockites and gneisses inland and are concentrated by wave action on the beach during the south-west monsoon. The most abundant mineral is ilmenite, forming 60 per cent. or more of all the heavy minerals. Garnet is abundant in some places, especially in South Travancore. Zircon, sillimanite, rutile and monazite come next in importance, in that order. The other minerals found are baddleyite, epidote, amphibole, etc. Some quartz is always present, and often some magnetite.

The Manavalakkurichi deposits have been worked for monazite since 1911 and for ilmenite since 1924 while the Nindakara deposits have been worked since about 1930. The ilmenite from the latter deposits contain 59-61 per cent. TiO_2 ; the excess over the theoretical content of ilmenite is thought to be due to the presence of the mineral *arizonite* ($Fe_2O_3.3TiO_2$), according to Hess and Gillson. The recovery of ilmenite from the sand is comparatively easy as it is concentrated in the first stages by tabling and electro-magnet Three analyses of Travancore ilmenite taken from an article on Titanium minerals by Hess and Gillson, are given below :—

——	Nindakars,	Manavalakurichi.	
	1	2	3
SiO_3	Ninda 1·4	1·4	1·53
TiO_2 . . .	60·3	54·3	53·36
Al_2O_3 . . .	n.d.	n.d.	1·11
$Fe^{\cdot}O_3$ . . .	24·8	15·5	14·17
FeO	9·7	26·0	26·71
MgO	n.d.	n.d.	1·01
MnO . . .	n.d.	n.d.	0·38
CaO	n.d.	*nil*	*nil*
d_3O_5 . . .	0·17	0·26	0.20
V_2O	0·26	0·20	0·03
$Cr_2.O.$ . . .	0·14	0·07	0·04

Malabar.—A strip of sand from a point 2 miles south of Blangad (10° 33′ 30″: 76° 1′ 30″) to Ponnani (10° 46′: 75° 55′ 30″), over a total distance of about 8 miles, contains ilmenite. The best part of this is the middle half where the deposit is up to 100 feet wide. The individual beds vary in thickness from ½ inch to 18 inches. An average concentrate from near Blangad showed 49 per cent. ilmenite, 15 per cent. garnet, 10 per cent. magnetite and 5 per cent. zircon.

Tinnevelly.—From the mouth of the Vaippar to near Panaiyur (9° 3′ : 78° 19′ 30″) there is a 4-mile stretch of sand, whose width is 20 feet to 200 feet. On the right bank of the stream 3 ilmenite rich bands are seen ½ to 4 inches thick, and some contain much garnet.

A deposit extends for 2 miles to the north-east from the right bank of the Kallar. It is up to 80 feet wide.

Near Veppalodai (8° 58′ : 78° 13′) two bands are seen 1 to 2 inches thick, for a length of 400 feet.

Near Taruvaikulam (8° 53′ 30″ : 78° 10′) is a patch which extends for 2 miles in a N.E. direction, and is up to 100 feet wide. A sample from this yielded 72 per cent. ilmenite, 14 per cent. garnet and 8 per cent. zircon.

There are several small deposits near Idindakarai (8° 10′ 30″ : 77° 44′ 30″). At Avudaiyapuram (8° 11′ : 78° 46′) a 30-inch thick band is seen for a length of 600 yards, and beyond that another band which is thinner. Other deposits, usually of limited extent, occur near the mouths of the Nambiyar and the Tambraparni; at a locality 1½ miles south of Tuticorin (8° 48′: 78° 9′). Between Vijayapati (8° 11′ 30″ : 77° 45′) and Idindakarai; and about half a mile south of Kuttankuli (8° 13′ : 77° 47′).

Ramnad.—Ilmenite-bearing sands occur at the following places:

East of the mouth of the Palar near Valinokkam.

East of Kilakkarai (9° 14′ : 78° 47′).

Near the promontary near Periyapattanam (9° 16′ : 78° 54′ 30″).

East of Sundaradasmadam (9° 17′ : 79° 10′) near Mandapam.

and also to its south are some deposits showing 50-60 per cent. ilmenite, associated with garnet, zircon, etc.

Tanjore.—Along a 2-mile stretch of the Coast north of Tranquebar

North of Ariyaman (9° 7′ 30″ : 79° 4′).

Another deposit extends from Tirumullaivasal (11° 14′: 79° 50′) southwards to Kanayampattanam for a distance of 1½ miles. Small patches are seen between Mimisal (9° 55′: 79° 8′ 30″) and Adirampattanam while the coastal sand dunes near Negapatam show the presence of ilmenite and garnet.

Dr. K. Jacob, who examined the Coastal sands in 1942-43 has made some estimates of the quantities of minerals available in the more important deposits.

Mineral.	Chowghat (Malabar).	Vaippar—Kallar (Tinnevelly)	Tranquebar (Tanjore)
	Tons	Tons	Tons
Ilmenite . . .	915,600	32,000	90,000
Magnetite . . .	180,000	2,100	20,000
Zircon . . .	9,000	1,400	3,600
Garnet . . .	229,000	9,000	20,000

Trichinopoly.—Ilmenite and titaniferous magnetite occur as grains and small lumps in the blotchy felspathic gneisses and associated pegmatites in an area of about 6 or 7 square miles around Kadavur (10° 35′ 30″ : 78° 11′ 30″). The streams and detrital sands in this area contain a fair concentration of these minerals.

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CHAPTER XLVII

WATER SUPPLY

Surface and sub-surface water is derived from rain. Rain falling on the surface of the earth partly flows on the surface (run-off water) and joins streams and rivers and partly sinks into the ground. The proportions of these varies greatly in accordance with local topographical and climatic conditions. Open-textured pervious rock, warm temperature, presence of grass and shrubby vegetation and absence of gradient—these encourage percolation. Close-textured, compact rock, frozen ground, bare surface and good slope encourage the loss of much of the rain water by run-off.

The popular belief that forests attract rain contains a modicum of truth. Forests keep the ground moist and cool, and rain-bearing winds precipitate their water content more easily over a cool forest than over a dry and hot barren country.

The run-off water goes into streams and rivers. If there is much rain fall in a short period, most of it flows off on the surface and contributes to floods. Small quantities of rain spread out over long intervals tend to percolate largely into the ground to augment the storage.

In addition to the surface flow there is also much water derived from seepage from the banks into the streams. In the dry season, when there is no visible flow at the surface, the sub-surface flow continues underneath the bed. River and stream beds are therefore never-failing sources of water supply.

Ponds and lakes are natural or artificial depressions on the earth's surface which are used as storage reservoirs for irrigation and other purposes. The bottoms of these are usually water-tight because of the accumulated clay and silt.

Water which percolates down fills up the pores in the soil and gradually travels into the rock below. A highly porous rock like sandstone can take in large quantities of water which can be drawn off later. Clayey rocks take in much water but do not easily yield it. In the more compact igneous and metamorphic rocks, storage space is provided by joint and cleavage planes, and fault and shear zones, as the rocks themselves are practically non-porous. In these rocks the best places for location of wells is at the intersection of major joint or fault planes which act as conduits. If these rocks are obscured on the surface by a soil cover, the location of successful wells in them becomes difficult. Now-a-days, however, it is possible to use geophysical methods to locate water-bearing sites and horizons. The term 'water-table' is used to designate the upper surface of a body of underground water. It is more or less a level surface but

tends to respond to variations in the topography. It is not necessarily deep in the dry districts ; for instance, in some parts of the Cuddapah basin, it is only 10 to 15 feet below the surface whereas in other parts it may be 40 to 50 feet below. The lower limit of underground water is variable. In porous sedimentary rocks it may extend to great depths provided a copious supply could enter it at the outcrop. In other types of rocks it often extends to a few hundred feet. The abundance of water depends on the structural and textural features of the rocks which provide the storage. Hence it should be realised that the supply would begin to diminish beyond a certain depth and finally disappear if the bore-hole is taken down deep enough.

Distribution

The Province can be divided roughly into three regions from the point of view of water supply.

1. *West Coast.*—This comprises the Western Ghats and the Coastal plains to their west which receives a high rain fall which in most places is over 100 inches per year. Though the rain fall is unevenly distributed through the year, there is some rain during every month. This region is therefore well supplied with water.

2. *East Coast.*—The eastern Coastal belt receives between 25 and 40 inches of rain per year. The northern part receives some rain during the southwest monsoon, but the whole region is favoured with precipitation during the period of retreat of the S.W. monsoon, in October and November. There are also the delta tracts—in Tinnevelly, Ramnad, Tanjore, Kistna and Godavari—which yield plenty of water from their water bearing sands.

3. *Interior Tract.*—The districts in the interior, comprising Coimbatore, Salem, North Arcot, Chittoor and the ceded districts, receive between 15 and 30 inches of rain per year. If this is spread out at suitable times, it should be adequate for agriculture. Unfortunately however, the rains are untimely in some years, giving rise to famine conditions.

Artesian Springs

Artesian springs can be had in places where the underground geological structure is such that the water is under a hydrostatic head sufficient to lift it to the surface. The aquifer is generally a porous sandstone sealed above and below by clayey strata. It is either directly exposed at the surface or is connected with beds which are so exposed and serve to bring in the rain water for storage in the aquifer.

There is a good artesian basin occupying a few square miles around Neyveli, Aziznagar and Kavanur near Vriddhachalan in the

South Arcot district. There are apparently 3 or 4 distinct water bearing horizons here, all in the Cuddalore sandstones. There are a number of flowing wells in this area.

A few artesian wells exist in and around Pondicherry in the same strata. In addition to the bore-holes in the town, there are a few to the south.

Artesian conditions are known to exist also near Bhimadolu in the West Godavari district, Tiruturaipundi in the Tanjore district, and in parts of Pudukkottai and Ramnad.

Though this Province is fairly well supplied with rivers and receives a satisfactory amount of rain fall, the rain is very unevenly distributed during the year. Moreover, there has been little effort at conservation of the river water except in the deltaic areas.

A potent cause of the intensification of dry conditions in the interior districts is the ruthless destruction of forests during the last few centuries. In the absence of forests, the surface of the ground loses moisture rapidly, all vegetation becomes parched up, and the water-table sinks low. The soil cover is lost rapidly by the action of wind and rain. The remedy for this state of things lies partly in re-afforestation and partly in the conservation of water of the rivers by forming artificial reservoirs by means of dams and regulating the flow of the stored-up water. Re-afforestation must be taken in hand seriously and done by systematic and sustained effort over a period of years. In this way most of the high ground and waste land which are now barren wastes can be clothed by forests, contributing thereby to greater conservation of water and soil and to an extension of land now available for agriculture. Money given for a planned project of afforestation of the interior districts will be well spent as it will contribute to the land becoming cool, moist and fertile and to the prosperity of the people living on it.

CHAPTER XLVIII

ZIRCON

Zirconium is a comparatively rare element distributed in small quantities in acidic and intermediate igneous rocks. The only two important minerals are zircon ($ZrSiO_4$) and Baddeleyite (ZrO_2). They occur as small crystals in the above-mentioned types of rocks. As they resist decomposition, they are usually left behind in the detrital cappings over these rocks or may be concentrated by streams flowing over them. The most useful source is the beach sands of certain countries.

Zircon ($ZrSiO_4$) crystallises in the tetragonal system, usually showing short prisms capped by pyramids. Its hardness is 7·5 and the specific gravity around 4·7. Owing to its high refractive index (1·92 to 1·96) the mineral shows high lustre and is used as a precious stone if transparent and without flaws. The zirconia content in the mineral varies from 60 to 66·8 per cent.

Baddeleyite (ZrO_2) occurs in tabular monoclinic crystals with a hardness of 6·5 and specific gravity of 5·5 to 6·5. The colour varies from yellow to brown and sometimes black.

Uses

Zircon is the source of zirconia (ZrO_2) which is a high grade refractory with a melting point near 2600° C. For this purpose the mineral is broken up by fusion with KHF_2 or by NaOH, then treated with sulphuric acid and separated and calcined. Zirconia is used in making super-refractory bricks, crucibles, retorts, muffles, etc., which are used for special purposes. Platinum and allied metals are now-a-days melted in zirconia crucibles. Zirconia refractory lining for walls of safes render these resistant to the oxy-acetylene flame.

Zirconia added to fused silica ware is said to prevent devitrification of the latter. Zircon compounds are used in ceramic compositions which have special electrical properties. They are also used in pigments, opacifying enamels, and in weighting silk, etc. Ferro-zircon has been used for making non-rusting steels with a high cutting power.

Distribution

Crystals of zircon have been noted in some pegmatites near Appiyode (8° 14′:77° 14′) in South Travancore, in the nepheline syenites of Sivamalai in the Coimbatore district and also in the rocks associated with a graphite deposit near Seitur, Ramnad district. These are, however, of academic interest only.

Zircon occurs as a constituent of the heavy sands along the sea-coast of Chowghat in Malabar, Vaippar-Kallar area of Tinnevelly and Tranquebar of Tanjore. The grains in these sands are usually colourless and transparent but sometimes exhibit zoning. The zircon forms a minor constituent of the sands, usually from 2 to 5 per cent.

The Travancore beach sands are first put through the electro-magnet to concentrate the ilmenite. Tabling afterwards gives a monazite concentrate which is again passed through high intensity magnetic separators. The tailings from the monazite concentration contain zircon, sillimanite, rutile, silica, etc. These are treated on wet tables so as to eliminate most of the quartz and sillimanite and then put through flotation cells which float off zircon from the associated rutile. The resulting zircon concentrate contains 10-15 per cent. impurities. The concentrate is again treated on dry tables to remove the lighter minerals and finally passed through high-intensity magnetic separators to remove the small amounts of associated rutile. The final concentrate is said to contain over 99 per cent. of zircon. Such a standard of purity is required for using zircon in the manufacture of super refractories. (P. Viswanathan: Beach minerals of Travancore. *Science and Culture,* XII, pp. 22-29, 1946.)

OUTPUT AND VALUE OF MINERALS PRODUCED IN MADRAS.

1898-1918 (£ 1=Rs. 15).

—		1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908
Gold . .	£	10,993	1,261	17	—	—	—	—	—	—	—	—
Magnesite	Tons	—	—	—	—	3,540	825	1,315	2,063	1,832	186	7,534
	£	—	—	—	—	—	—	351	550	488	50	2,009
Manganese Ore.	Tons	60,449	87,126	92,458	76,463	68,171	63,452	—	—	—	—	—
Mica (Export).	Cwt.	3,264	3,206	7,071	19,517	4,421	3,755	4,840	8,280	24,420	15,865	11,249
	£	21,183	21,628	26,035	46,405	16,875	19,329	—	—	—	—	—
Salt . .	Tons	251,875	268,962	322,244	339,544	358,450	244,923	356,834	388,646	412,717	353,271	435,120

—		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Diamonds .	Carats	36	65	50	9	79	—	—	—	—	—
	£	1,042	577	475	400	1,769	—	—	—	—	—
Gold . . .	Oz.	—	2,332	5,284	7,269	11,019	19,873	23,870	22,371	20,529	17,891
	£	—	10,120	20,835	28,499	43,194	82,959	101,324	94,789	87,066	67,219
Graphite . .	Tons	—	259	54	—	—	—	—	—	—	—
	£	—	517	108	—	—	—	—	—	—	—
Magnesite . .	Tons	737	5,182	3,490	15,379	14,086	399	7,450	17,540	18,192	5,773
	£	196	1,382	1,047	4,614	4,153	130	3,973	14,032	14,554	4,618

OUTPUT AND VALUE OF MINERALS PRODUCED IN MADRAS—*contd.*

1898-1918 (£ 1=Rs. 15).

—		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Salt	Tons	309,583	464,607	414,521	484,405	348,287	298,862	345,714	481,091	396,913	596,671
Granite and Gneiss	Tons	20,224	114,897	85,402	91,458	62,001	76,226	94,618	305,131	58,878	116,296
	£	4,045	1,248	1,951	3,938	2,332	1,465	2,784	4,927	2,466	4,518
Limestone and Kankar.	Tons	—	—	—	—	—	65,419	11,250	13,964	9,541	6,028
	£	—	—	—	—	—	2,547	572	794	551	502
Laterite . .	Tons	119	11,736	107,484	68,981	90,752	93,630	94,574	200,696	97,042	110,515
	£	8	2,049	1,654	2,199	3,489	3,035	3,495	5,117	3,905	5,048
Corundum . .	Cwt.	—	1,686	3,491	2,931	1,951	689	37	38	26	25
	£	—	323	1,660	532	324	104	12	13	10	10
Steatite . .	Tons	—	28	292	48	579	295	603	184	202	748
	£	—	101	561	25	4,489	2,308	1,146	704	979	1,252
Mica	Cwt.	8,948	3,586	7,462	13,484	10,861	5,990	3,894	15,675	6,050	6,545

—		1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Diamonds . . .		—	—	—	—	—	—	—	—	—	—
	Oz.	11,018	13,645	10,108	8,388	1,519	3,646	288	930	2,395	—
	Rs.	6 10,195	8,03,535	7,21,359	6,08,673	1,01,016	2,38,605	16,517	53,219	1,37,320	—

Magnesite . .	Tons	13,012	11,300	17,152	18,417	19,336	24,427	29,620	28,676	16,966	22,542
	Rs.	1,56,144	1,35,600	2,05,824	2,21,004	2,32,032	2,93,124	4,14,630	3,41,925	2,02,656	1,41,742
Mica . . .	Cwt.	8,321	11,928	4,376	1,301	8,814	11,273	14,779	11,584	9,546	8,947
	Rs.	5,25,800	6,14,414	2,10,445	95,481	3,38,615	5,47,343	6,46,004	6,43,684	6,32,936	4,37,396
Salt	Tons	552,308	453,547	446,113	465,929	485,569	407,544	336,605	481,826	543,081	448,538
Granite and Gneiss	Tons	53,930	12,060	26,218	16,785	5,992	7,065	8,211	14,040	16,055	72,323
	Rs.	13,600	3,800	14,085	5,700	385	1,435	1,613	8,776	8,981	7,597
Limestome and Kankar.	Tons	17,490	12,759	17,460	20,065	20,720	13,271	13,996	12,628	13,518	16,180
	Rs.	10,340	11,430	64,065	72,330	69,030	13,442	16,519	22,772	13,668	16,436
Laterite . .	Tons	103,314	93,988	58,751	150,028	80,414	75,525	93,331	157,828	94,386	87,585
	Rs.	81,410	87,690	45,220	67,860	56,955	64,090	49,872	97,683	82,684	81,715
Clays .	Tons	—	—	—	12	110	107	708	265	1,094	7,366
	Rs.	—	—	—	70	200	107	4,032	272	434	1,893
Corundum . .	Cwt.	—	—	—	—	—	—	—	17	52	21
	Rs.	—	—	—	—	—	—	—	4,333	7,765	2,780
Ochre . .	Tons	250	100	—	—	435	325	340	275	350	325
	Rs.	1,500	660	—	—	5,400	4,375	4,600	3,750	4,750	4,500
State . . .	Tons	—	—	213	108	113	8	—	—	—	—
	Rs.	—	—	340	206	228	15	—	—	—	—
Steatite . .	Tons	529	574	569	613	967	916	799	548	882	213
	Rs.	21,414	17,529	19,853	18,267	25,364	26,531	22,665	15,170	23,355	9,271

OUTPUT AND VALUE OF MINERALS PRODUCED IN MADRAS—*contd.*

—		1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
Magnesite.	Tons	22,134	15,563	4,978	13,492	11,131	11,859	12,840	12,966	23,782	23,052	29,903
	Rs.	1,30,722	67,978	21,540	64,482	67,557	71,208	75,905	77,248	1,40,708	1,34,876	1,79,079
Mica . .	Cwt.	10,194	11,348	6,958	8,369	8,005	9,185	9,495	13,689	15,767	22,915	22,648
	Rs.	5,56,030	6,53,761	3,52,030	3,89,925	4,09,737	3,76,071	3,94,514	5,09,471	6,64,092	6,08,247	9,65,029
Salt . .	Tons	421,208	341,756	555,449	446,556	490,510	499,268	460,257	349,190	421,014	453,954	858,692
Granite and Gneiss.	Tons	10,817	192,127	211,203	157,464	130,274	174,330	120,665	96,127	129,460	165,989	165,584
	Rs.	6,760	3,28,816	3,18,506	1,75,564	1,72,828	2,19,865	1,39,203	1,05,369	1,34,952	1,89,185	1,76,670
Limestone and Kankar.	Tons	18,375	16,459	13,215	19,640	13,826	83,804	—	—	—	—	—
	Rs.	17,750	8,989	8,390	12,737	8,562	30,366	—	—	—	—	—
Laterite	Tons	73,568	77,059	63,162	73,354	51,752	69,859	75,285	20,806	141,943	189,757	172,617
	Rs.	81,213	87,905	60,263	67,796	44,400	54,170	45,946	15,262	76,200	93,570	82,469
Clays .	Tons	20,106	1,367	5,196	3,102	182,588	192,288	110,569	128,797	104,547	114,643	93,108
	Rs.	2,058	495	2,705	1,005	70,222	86,146	39,003	40,0[illegible]3	21,066	20,271	17,119
Corundum	Tons	34	30	—	—	—	—	—	—	—	—	—
Ochre .	Tons	325	375	300	300	363	251	427	1,021	724	272	272
	Rs.	4,500	4,050	3,550	3,550	3,126	2,365	3,656	7,676	3,795	2,558	2,558
Steatite	Tons	270	255	197	220	244	246	484	374	303	7,558	8,494
	Rs.	6,181	5,398	4,075	4,764	5,015	4,157	4,594	8,447	4,640	11.451	26,887

—		1940	1941	1942	1943	1944	1945	1946	1947
Apatite		117	80	332	1,196	228	524	243	853
Asbestos		31·25	29	60	33	58	38	18	—
Barytes		17,740	22,145	10,008	7,894	13,567	22,703	28,874	24,225
Bauxite		—	—	1,122	2,031	2,313	2,989	1,662	—
Building stones	Granite	163,685	180,374	872,700	282,302	707,947	634,732	361,377	321,872
	Laterite	—	—	—	47,520	751,106	96,714	164,277	56,480
	Napa or slab stone.	—	272	293	—	15,106	10,178	2,112	9,560
	Miscellaneous	666,973	669,169	691,696	211,010	319,057	225,458	220,218	577,427
Calcite		—	—	86	—	—	—	495	452
Celestite		—	29	556	734	—	—	—	—
Chromite		—	170	525	500	500	—	274	153
Clay		94,483	174,981	275,816	108,608	260,222	109,561	346,036	106,700
China Clay		16,231	1,523	985	1,686	2,396	2,514	1,379	2,734
Corundum		—	1	22	7	42	19	20	—
Felspar		—	—	22	—	117	497	82	228
Garnet		—	4	—	—	23	—	—	—
Gold (Oz.)		—	—	—	22	361	38	55	7

OUTPUT AND VALUE OF MINERALS PRODUCED IN MADRAS—*concld.*

—	1940	1941	1942	1943	1944	1945	1946	1947
Graphite	—	—	—	—	—	91·4	95	—
Gypsum	18,714	16,228	17,656	10,299	14,316	21,004	12,747	16,380
Ilmenite	263,152	129,040	49,188	37,789	100,794	172,086	185,023	253,409
Iron ores	2,109	—	—	—	—	—	—	—
Kyanite	4	110	2	—	—	—	—	—
Limestone and Kankar	257,851	158,540	268,075	195,739	265,177	461,680	559,627	489,418
Magnesite	37,305	36,435	41,639	42,734	37,950	25,434	43,246	51,536
Manganese	76,398	26,135	10,016	10,911	3,929	2,158	16,414*	44,695
Mica (Cwts.)	26,688	15,121	18,344	20,271	11,929	17,316	15,533	14,063
Monazite	4,146	3,475	1,300	1,908	2,016	1,567	60	615
Ochre { Red			206					
Ochre (Red and Yellow)	392	1,042		79	1,253	1,320	1,957	4,504
Ochre { Yellow			897					
Phosphatic nodules	117	51	120	462	311	524	243	—
Quartz	—	—	189	4	24	60	—	—
Road metal	—	—	—	—	132,746	34,766	53,906	206,051
Rutile	919	1,861	2,259	2,612	1,646	610	257	157

—	1940	1941	1942	1943	1944	1945	1946	1947
Salt	369,620	540,711	638,919	459,304	508,220	614,762	515,636	628,147
Sand	—	—	—	—	5,241	4,621	9,330	5,000
Sillimanite	221	204	235	244	41	30	66	236
Slate Stone	—	272	293	—	—	73	216	477
Steatite (Potstone)	10,953	250	13,483	—	478	354	249	1,069
Zircon	3,137	2,502	273	—	755	1,020	466·5	—

*Sandur.

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MADRAS

INDEX.

Subject.	Pages.
A	
Abrasives	16-21.
Abrasives, artificial	17, 21.
Abrasive Silt	20.
Agate	115, 258.
Aiyengar, N. K. N.	ii, 32, 45, 79, 95, 141, 147, 276.
Alirox	21, 36.
Alum	23.
Alunogen	23.
Amazon stone	106, 117.
Amosite	24.
Anamalais	2.
Anantapur District	2, 6, 8, 18, 19, 26, 33, 39, 58, 86, 92, 100, 117, 121, 181, 272.
Andalusite	154.
Anhydrite	134, 135.
Anorthosite	91, 93, 94.
Antimony	22.
Apatite	8, 13, 115, 252, 297.
Aquamarine	116.
Arabian Sea	3, 5.
Archaean	5, 6, 7, 8, 13, 50 (minerals in 14).
Arcot, North District	2, 5, 20, 32, 39, 59, 107, 139, 146, 234, 245, 274, 280, 289.
Arcot, South District	2, 11, 14, 18, 62, 107, 146, 165-170, 182, 255, 261.
Arogyaswami, R. N. P.	133, 165, 181.
Asbestos	13, 24-28, 297.
Asbestos, Amphibole	24, 26.
Asbestos, Serpentine	24.
Auk Shales	10.
B	
Baddeleyite	291.
Balasundaram, M. S.	ii, 30, 51, 142, 216, 269.
Balfour, E.	1, 22, 91, 140.
Ball, V.	99, 102.
Banganapalle	21.
Banganapalle formation	9, 10.
Barakar sandstones	10, 12, 72.
Barite	13, 14, 28-34, 297.
Bauxite	35-36, 297.
Bellary District	20, 21, 22, 39, 86, 101, 107, 120, 145, 181, 199, 216, 218, 244, 272.
Benza, P. M.	113, 140, 200.
Beryl	13, 116, 231.
Beryllia	261.
Biotite	220.
Blanc fixe	30.
Blanford, H. F.	1, 150, 253.
Blanford, W. T.	1, 70, 71.
Bose, P. N.	132, 248.
Boswell, J. A. C.	82.
Braunite	209.
Buchanan-Hamilton	1.
Building stones	14, 37-40, 297.

Subject.	Pages.
Calcareous Sandstone	195.
Calcite	11, 14, 15, 297.
Calicut	50.
Cardamom Hills	2.
Carmichael	22.
Cauvery River	4, 39.
Celestite	11, 14, 32, 276, 297.
Cement, Keene's	134.
Cement, Portland	134,173,175,189,190.
Cement, Oxychloride	193, 206.
Cement, Parian	135.
Ceylon	5, 6, 8, 11, 12.
Chalk	11, 14, 21, 179, 180, 183.
Chalk Hills	44, 199, 205.
Charnockite	2, 3, 7, 8, 13, 37, 114, 227.
Chert	19.
Chetty, Gopalkrishnamah	33, 103.
Cheyair Series	55, 57.
China Clay	20.
Chingleput District	2, 6, 10, 13, 20, 38, 60-62, 118, 136, 146, 261.
Chintalpudi Sandstone	10, 38.
Chittoor District	2, 6, 8, 39, 107, 118, 146, 234, 274.
Chrysoberyl	116.
Chrysotile	24, 25, 27.
Chromite	13, 41-47, 260, 261, 297.
Ciment fondu	35.
Coal	10, 13, 70-76.
Clay, fire	49, 260, 261.
Clay, stoneware	50.
Clay, brick	50.
Clay, analysis	54, 64, 66, 68.
Climate	3.
Coast, Western	3, 6.
Coast, Eastern	3.
Cochin	3.
Coimbatore District	2, 8, 18, 20, 21, 26, 27, 32, 39, 79, 87, 96, 116, 118, 119, 122, 132, 150, 154, 155, 188, 236, 274.
Columbite-tantalite	77-79, 235.
Comorin, Cape	2.
Continental Shelf	6.
Copper	13, 80-88.
Coorg	199.
Coral Limestone	11, 38.
Cordierite	89-90, 116.
Cornwall Stone	106, 108.
Coulson, A.	30.
Cotter	248.
Corundum	8, 13, 17, 18, 91-98, 116, 294, 295, 296, 297.
Corundum, belt	45.
Cretaceous	6, 11, 14, 15, 38.
Crookshank, H.	125, 127.
Crocidolite	24.
Cuddapah District	2, 3, 6, 8, 13, 19, 20, 22, 23, 25, 28, 29, 39, 55-56, 86, 101, 117, 119, 141, 157, 178, 208, 243, 280.
Cuddapah Basin	6, 8, 39, 68.
Cuddapah Formations	8, 9, 10, 13, 20, 23, 38, 50, 269.
Cuddapah Formations, Minerals in	14.

SUBJECT.	PAGES.
Cuddapah Slabs	10, 37, 39, 280.
Cuddalore Sandstone	6, 11, 12, 14, 19.
Cumbum Shales	9.
D	
De Bournon	1, 91.
De la Tour	1, 92.
Dharwarian	2, 3, 5, 6, 7, 13.
Diamond	10, 16, 17, 18, 99-105, 117, 293, 294.
Diatomite	20.
Dickins, E. K.	21, 36.
Districts, Areas of	2.
Doddabetta	3.
Dolomite	13, 172-197.
Dolomite, Analysis	175, 176, 179, 180, 182.
Dubey, V. S.	141, 147.
E	
Eastern Ghats	2, 3, 5, 6, 8.
Emery	16, 18, 91.
F	
Feldspar	8, 13, 20, 106-109, 117, 222, 297.
Fermor, L. L.	115, 212, 213.
Ferromanganese	210, 218.
Foote, R. B.	1, 44, 86, 100, 132, 136, 140, 145, 146, 150, 162, 163, 200, 204, 214, 272, 274.
Flint	19, 258.
Fluorspar	110-111.
Fuchsite	220.
G	
Galena	22.
Ganapati, S. V.	279.
Garnet	6, 8, 13, 14, 16, 18, 112-114, 117, 287, 297.
Gas, Natural	250-251.
Gemstones	115-119.
Geology	6.
Ghose, A.	33, 104, 214, 273.
Ghosh, P. K.	96, 131.
Gneisses	6, 7, 8, 13, 37, 39, 294, 295, 296.
Gneisses, alteration to clay	62, 67.
Godavari, East District	2, 20, 36, 38, 52-53, 70-73, 96, 102, 115, 117, 131, 174, 242, 248, 250.
Godavari, West District	2, 6, 10, 20, 36, 38, 53-54, 132, 141, 174, 228, 242, 261.
Godavari River	4.
Gold	13, 120-129, 293, 294, 297.
Gondite	209.
Gondwana Formation	6, 10, 11-14, 38, 50, 58, 60, 64.
Granite	8, 13, 37, 39, 294, 295, 296, 297.
Grabau, A. W.	134.
Graphite	8, 13, 130-133, 261, 293, 298.
Grindstone	19.

Subject.	Pages.
Gulcheru Quartzite	9.
Guntur District	2, 5, 6, 8, 10, 13, 38, 55, 96, 102, 117, 136, 141, 145, 157, 176, 243.
Gypsum	11, 14, 15, 64, 134-137, 276, 298.
H	
Hardness scale	16.
Hatch, F. H.	124.
Hausmannite	209.
Hayden, H. H.	87, 88, 122, 259.
Heath, J. M.	44, 116, 139.
Hematite	13, 138.
Hess and Gillson	285.
Heyne, B.	1, 82, 86, 199.
Holland	1, 32, 44, 96, 140, 146, 150, 200.
Hollandite	209.
Honing Stones	20.
Howard, Henry	99, 102.
Hyderabad	13, 74.
I	
Ilmenite	14, 284-287, 298.
Ilmenite, Analysis	285.
Iron ore	7, 13, 138-153, 298.
Iron ore, analysis	143, 149.
Iyer, V. S. Sambasiva	256.
J	
Jacob, K.	11, 113, 162, 287.
Jacobsite	209.
Jaffna Beds	6, 11.
Jammalamadugu Formation	37, 39.
Jasper	39, 258.
Javadi Hills	3.
Jayaraman, N.	254, 276.
K	
Kalrayan Hills	3, 4.
Kanara, South District	2, 18, 20, 36, 65-67, 96, 118, 162, 236, 247, 275.
Kankar	172, 177, 181, 182, 194, 294, 295, 296, 298.
Kaolin (China clay)	13, 49, 50, 51, 58, 63, 65-68, 106.
Kayal	3, 5.
Kelsall	22.
Khondalite	3, 8, 37, 112, 227.
King, W.	1, 20, 23, 33, 44, 73, 82, 84, 103, 117, 123, 140, 158, 164, 200, 211.
Kistna River	4.
Kistna District	2, 38, 42, 47, 102, 117, 132, 141, 176, 229, 250, 279.
Kodurite	8, 209, 212.
Koilkuntla Limestone	9.
Kindavidu Hills	38.

Subject.	Pages.
Kortalaiyar	4.
Krishnan, M. S.	23, 30, 269.
Krishnappa, A.	25, 27.
Kundair Formation	37.
Kurnool District	2, 6, 8, 9, 13, 19, 20, 21, 25, 33, 38, 39, 57-58, 86, 103, 117, 143, 159, 178, 199, 208, 216, 243, 269, 270, 273, 280.
Kurnool System	9, 10, 13, 14, 18, 20, 38, 99.
Kuvam (Cooum)	4.
Kyanite	13, 118, 154-156, 260, 298.
L	
Lake, P.	1, 101, 150.
Lake Pulicat	5.
Lake, Colaire	5.
Lake, Kaliveli	5.
Laterite	14, 15, 40, 66, 67, 294, 295, 296, 297.
Lead-Ores	33, 157-160.
Leighton, D. E. W.	75.
Lepidolite	220.
Lignite	11, 14, 15, 161-171.
Lignite, Analysis	163, 164, 170.
Limeshells	178.
Limestone	10, 13, 14, 38, 172-197, 294, 295, 296, 298.
Limestone, Tufaceous	39.
Limestone, Lithographic	176, 177, 179.
Limestone, Coral	196.
Limestone, Analysis	175, 176, 179, 180, 182, 196.
Limonite	138.
Lithopone	29, 30.
Lodestone	208.
Lydian Stone	20[illegible]
M	
Maclaren, J. M.	216.
Madras District	2.
Madura District	2, 5, 20, 39, 78, 107, 189, 237, 249.
Magnesite	13, 198-207, 260, 261, 293, 295, 296, 298.
Magnesite, Analysis	204.
Magnetite	18, 138, 208, 287.
Malabar District	2, 3, 14, 20, 36, 65, 66, 123, 139, 150, 162, 236, 247, 280, 284, 286, 292.
Mangalore	50.
Manganese ore	13, 209-219, 293.
Manganite	209.
Marble	38, 172, 174, 176, 189, 190.
Marcasite	278.
Mica	13, 220-240, 293, 294, 295, 296, 298.
Micanite	222-223.
Microcline	8, 106, 108.
Middlemiss, C. S.	1, 74, 93, 95, 96, 140, 147, 200.
Middleton, C.	78.
Minerals, Distribution of	12.

SUBJECT.	PAGES.
Minerals, output and value	293-299.
Miocene	6, 11.
Molybdenite	130, 248.
Molybdenum	248-249.
Molybdite	248.
Monazite	14, 298.
Monsoon	3.
Mountains	2.
Mullite	154, 260-261.
Muscovite	220-240.
Muscovite, Analysis	221.
Muzzy, C. F.	1, 78.
Mysore	2, 3, 7.
N	
Nallamalais	3, 22.
Narayanan, P. I. A.	43, 46, 253.
Narayanaswamy, S.	ii, 78, 133.
Narji Limestone	9, 10.
Nellore District	2, 3, 5, 6, 8, 9, 18, 20, 32, 38, 58, 78, 81-84, 108, 110, 112, 116, 117, 136, 137, 145, 155, 177, 229-234, 245, 255, 261, 269, 270-273.
Newbold, T. J.	1, 22, 33, 44, 82, 84, 86, 91, 92, 102, 113, 116, 140, 158.
Nilgiri Hills	2, 3, 5, 6, 8, 36.
Nilgiri District	2, 8, 26, 39, 113, 123-127, 150, 161, 237.
Nitre	268.
O	
Ochre	13, 14, 241, 295, 296, 298.
Opal	118, 258.
Oldham, C. Æ.	1.
Oldham, R. D.	12.
Oldham, T.	1.
P	
Palkondas	3.
Palni Hills	2, 4, 36.
Peat	161-162.
Pegmatites	32, 45, 222.
Phlogopite	220, 221, 227-228.
Phosphates	252-257, 298.
Phosphatic Nodules	298.
Phosphatic nodules, Analysis of	255.
Pichamuthu, C. S.	163.
Pigments, Mineral	241-247.
Pigments, Mineral, Analysis of	245, 246.
Pillay, D. S.	51, 59.
Plaster of Paris	134.
Poilay, M.	164.
Polianite	209.
Pondicherry	20, 164, 255, 290.
Posnjak	134.
Potstone	272-275, 299.
Psilomelane	209.

Subject.	Pages.
Pudukottai	19, 40, 150, 246.
Pulicat Lake	20.
Pulpstone	19.
Punnaiya, V. V.	42.
Pyrite	23, 123, 125, 138, 278, 280.
Pyrolusite	209.
Pyroxenite	222.
Pyrrhotite	278, 250.
Quartz	13, 19, 59, 118, 222, 258-259.
Quartz vein	45.
Quartz-Schist	37.
Quartzite	13, 19, 37, 59.
Quilon	50.
R	
Rajahmundry Sandstone	52, 53.
Ramacharlu, P.T.	46, 268.
Ramnad District	38, 40, 113, 189, 247, 261, 286.
Ranganathan, M. K.	52.
Rao, G. Gopal	46, 51, 53, 54.
Rainfall	4.
Rao, M. Vinayak	26, 281.
Refractories	41,260-262.
Reh	267.
Rhodocrosite	209.
Rivers	4.
Road stones	263-264, 298.
Roy, B. C.	ii, 85, 136, 158, 159, 230.
Ruby	91, 93.
Rutile	14, 283, 298.
S	
Salem District	2, 3, 4, 5, 8, 18, 20, 21, 26, 27, 38, 42, 44-46, 47, 79, 92, 107, 116, 140, 146-149, 184-188, 199-203, 208, 235, 274,
Salt	294, 299.
Salt, Soda	267-268.
Salt, Potash	267.
Samarskite	13, 231, 233.
Sands	265-266, 299.
Sands, Foundry	265.
Sands, Glass	14, 265-266.
Sands, Others	265.
Sandstone	13, 14.
Sandstone, Calcareous	195.
Sandur	22, 214-216, 218, 244.
Sapphire	91.
Sclerometer	16.
Scott, A.	22.
Sen, S. N.	ii, 71, 85.
Sengupta, K. K.	84, 125, 142.
Serpentine	24, 25, 119.
Shell-limestone	182, 183, 195.
Shevaroy Hills	3, 4, 8, 18, 19, 35, 36, 44.

Subject.	Pages.
Silicospiegel	210.
Silimanite	6, 8, 13, 154-156, 260, 299.
Sitaparite	209.
Sittampundi	45.
Sivaganga	10. 247.
Slate	13, 38, 39, 269-271, 295, 299.
Sodium Salts	267.
Spiegeleisen	210.
Spinal	18.
Steatite	13, 21, 272-275, 294, 295, 296, 299.
Steel	138, 139.
Steel, Wootz	139.
Stellite	41.
Stone, Ornamental	14.
Strontium	276-277.
Strontianite	276.
Structure, geological	5.
Subramaniam, A. P.	ii, 45, 51.
Subramanyam, V.	ii, 71.
Sulphur	278-282.
Sulphur, Native	279.
Sulphur, Bacteria	279.
Syenite	8.
T	
Tadpadri Shales	9.
Talc	272-275.
Tambraparni	4.
Tanjore District	2, 11, 12, 19, 40, 118, 162, 182, 250-251, 286, 292.
Tantalite-Columbite	13, 77-79, 235.
Tavernier, J. B.	1, 99, 102.
Tertiary	6, 11, 14, 15, 62, 67.
Thiagarajan, R.	ii, 51.
Thoria	261.
Tinnevelly District	2, 5, 11, 12, 19, 20, 38, 39, 113, 132, 136, 191-196, 208, 239, 286.
Tipper, G. H.	284.
Titanium	283-287.
Tourmaline	119.
Traps, Deccan	35.
Travancore	3, 5, 19, 23, 67-68, 155, 163, 239, 261, 283-285, 291-292.
Trichinopoly District	2, 10, 11, 12, 14, 18, 19, 20, 32, 39, 64, 78, 89, 96, 107, 113, 116, 118, 119, 132, 135, 139, 140, 182, 199-203, 208, 234, 246, 248, 253-255, 274, 276, 287.
Turner, H. G.	200, 212.
U	
Ultrabasic Rock	8, 13, 198, 204.
Umber	241.
Upadhaya, G. V. D.	165.
Uttatur Stage	21, 64.

SUBJECT.	PAGES.
V	
Vaigai	4.
Varshanad Hills	2.
Vanstavern	71, 73.
Vempalle Limestone	9, 25, 27, 29, 39.
Vempalle Shales	23.
Venkatram, M. S.	ii, 27, 30, 215.
Venkayya, P.	99, 100.
Vermiculite	221.
Velikonda Hills	3.
Viswanathan, P.	155, 284, 292.
Vizagapatam	2, 8, 22, 36, 38, 51-52, 54, 89, 96, 112, 119, 131, 141, 155, 174, 211-213, 227, 256, 273.
Voysey	1.
Vredenburg	249.
W	
Wadia, D. N.	6.
Walker, H.	75.
Walker, T. L.	1, 78, 174.
Wall, P. W.	33, 70, 158.
Warth, H.	93, 253, 255, 276.
Warkalli Beds	11, 23.
Water	288-290.
Water, Artesian	289.
Western Ghats	2, 3, 5.
Witherite	29.
Wulfenite	248.
Z	
Zinnwaldite	220.
Zircon	14, 119, 287, 291-292, 299.
Zirconia	261, 291.

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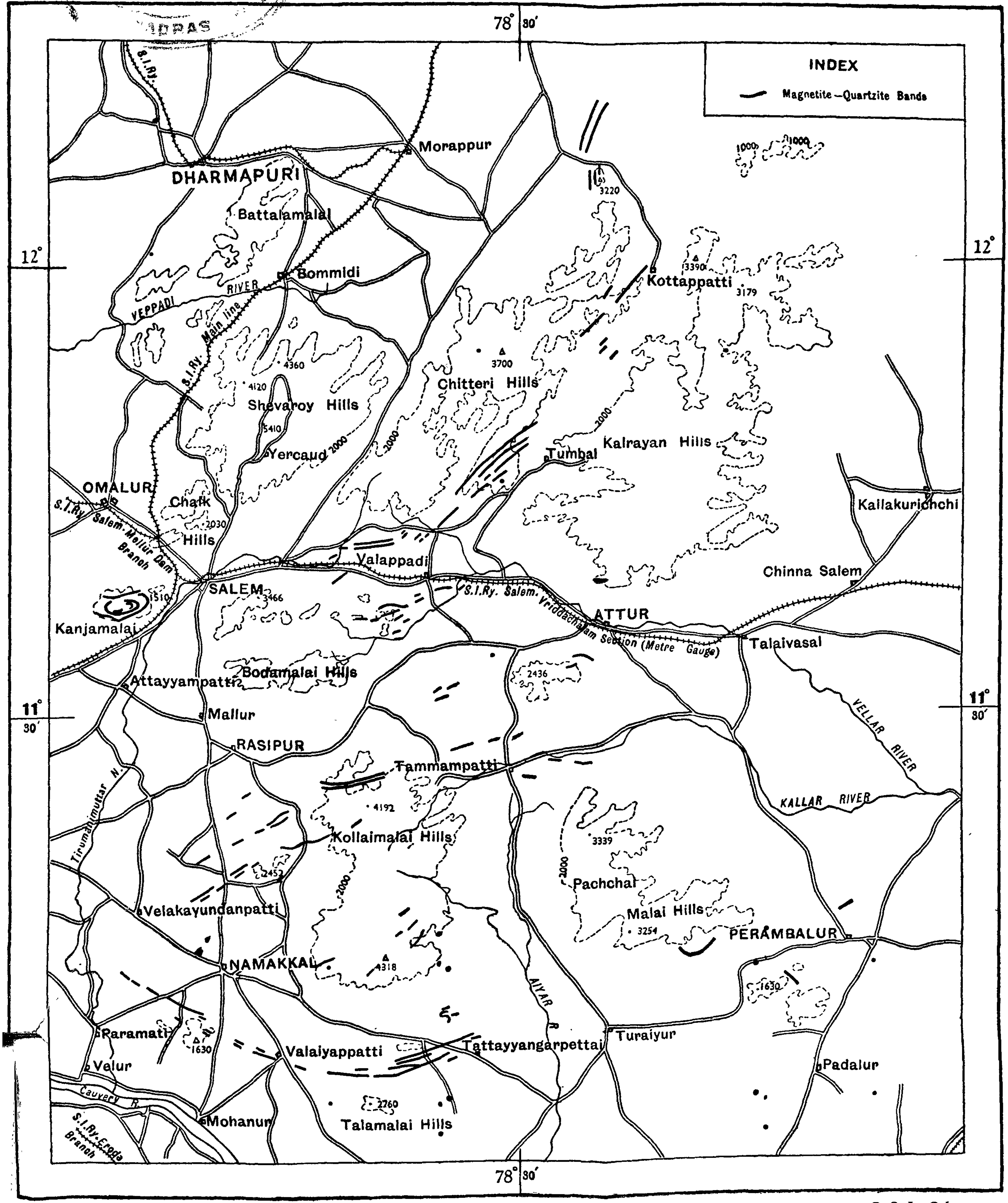

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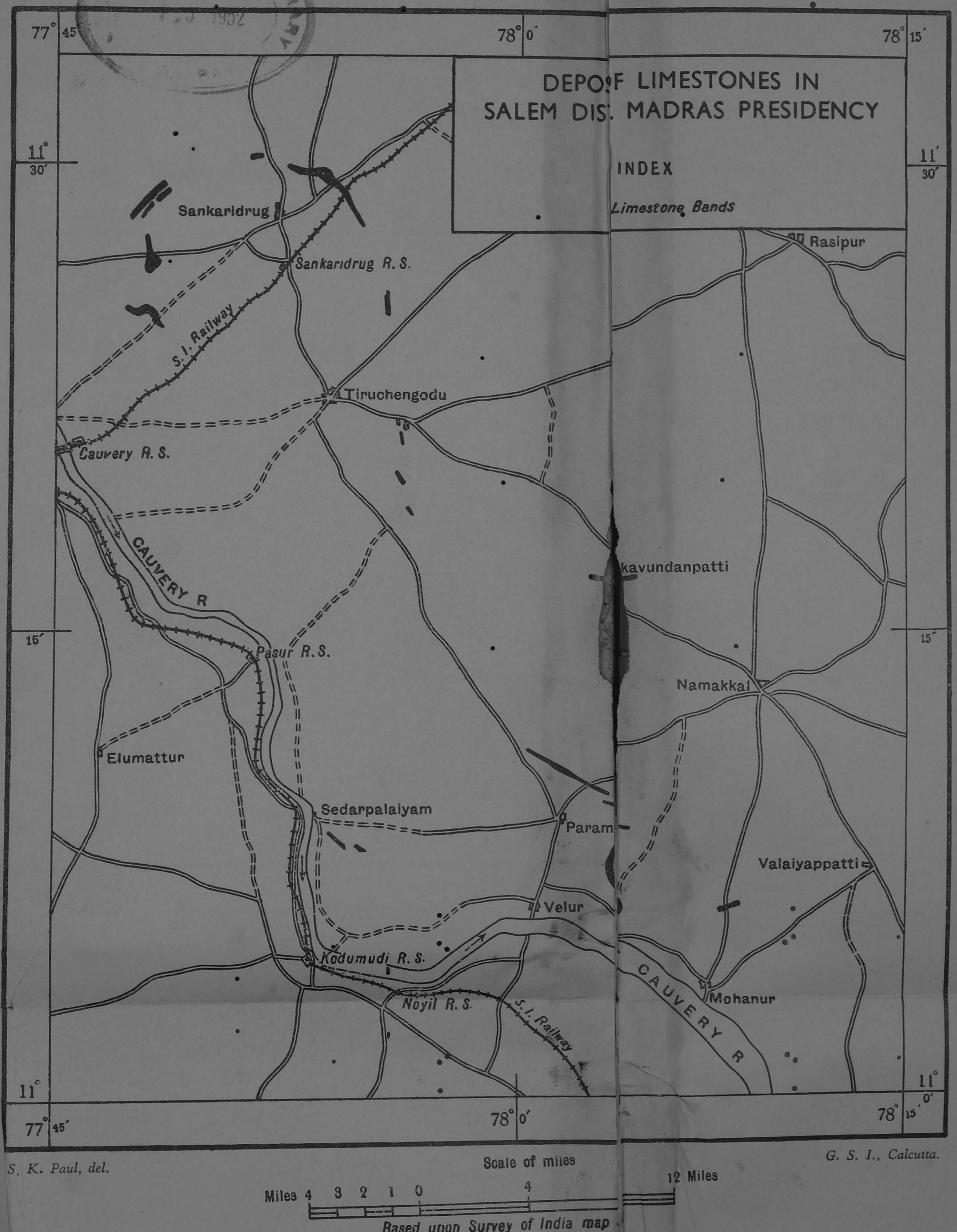
IRON ORES OF SALEM AND TRICHINOPOLY DISTRICTS MADRAS PRESIDENCY

Scale of Miles

Miles 10 8 6 4 2 0 10 20 30 Miles

Based upon Survey of India map 57/L & 58/I



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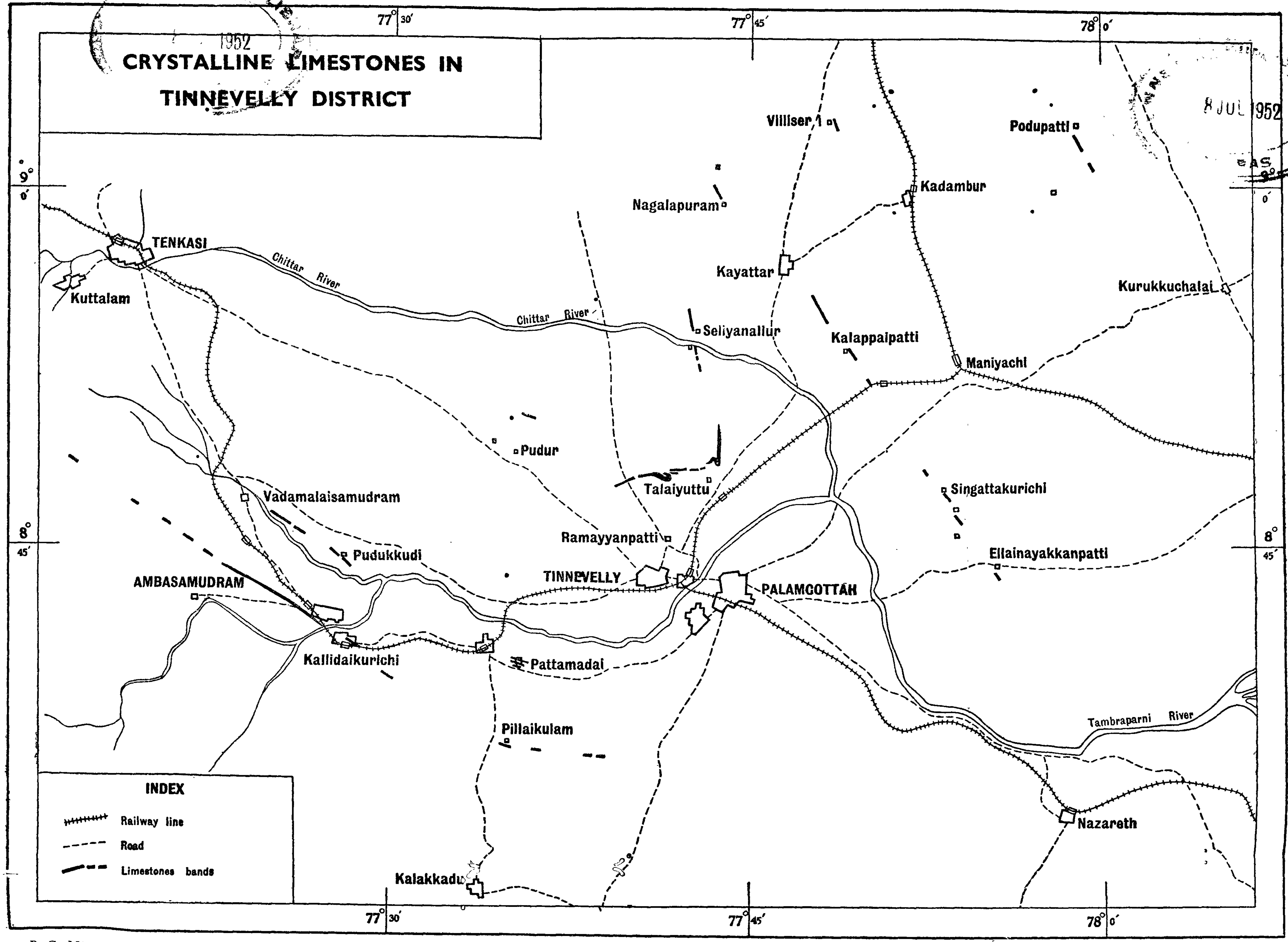

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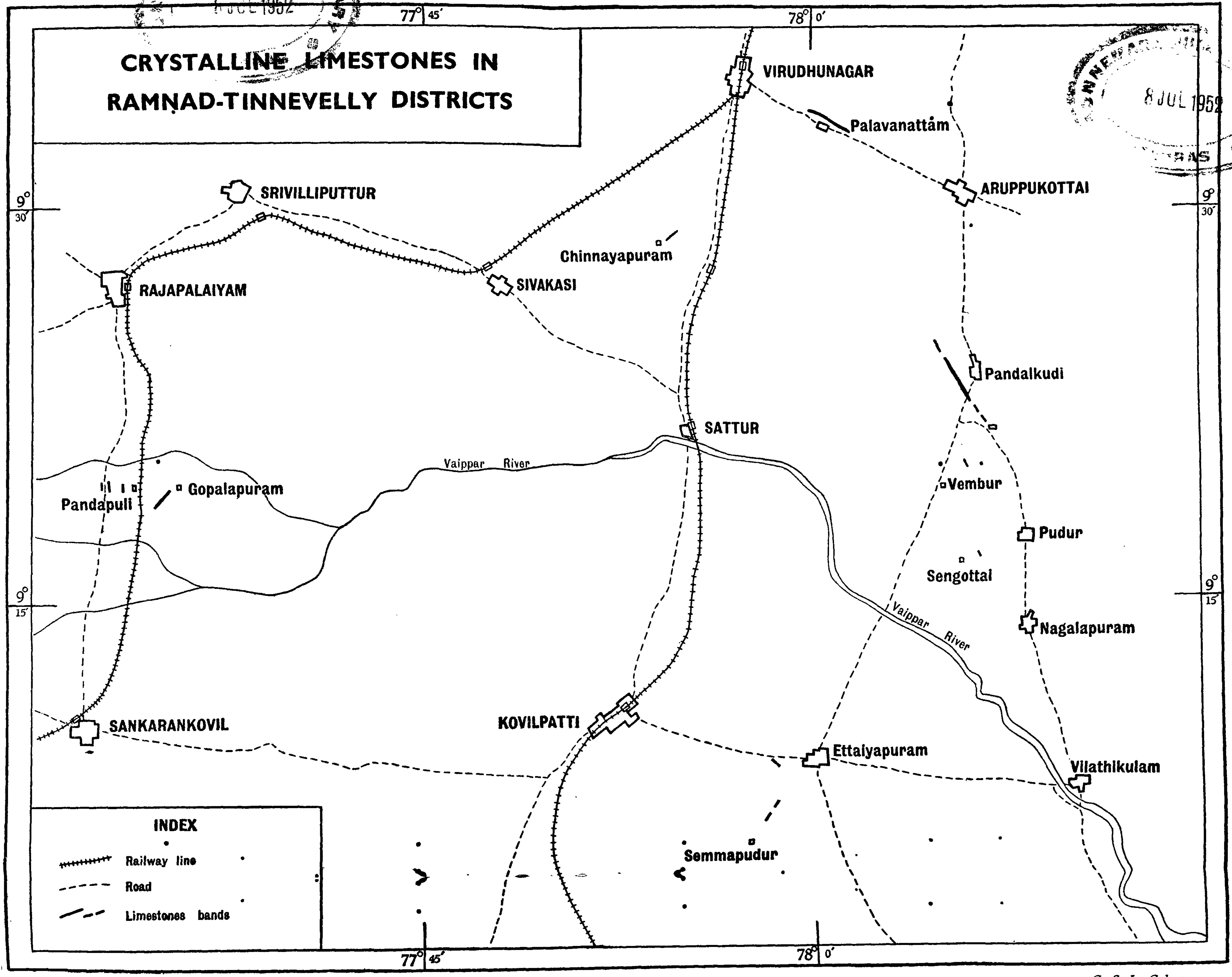

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MAGNESITE AREA, CHALK HI SALEM DISTRICT.

Scale of

Furlongs 8 6 4 2 0 1 2 3 Miles

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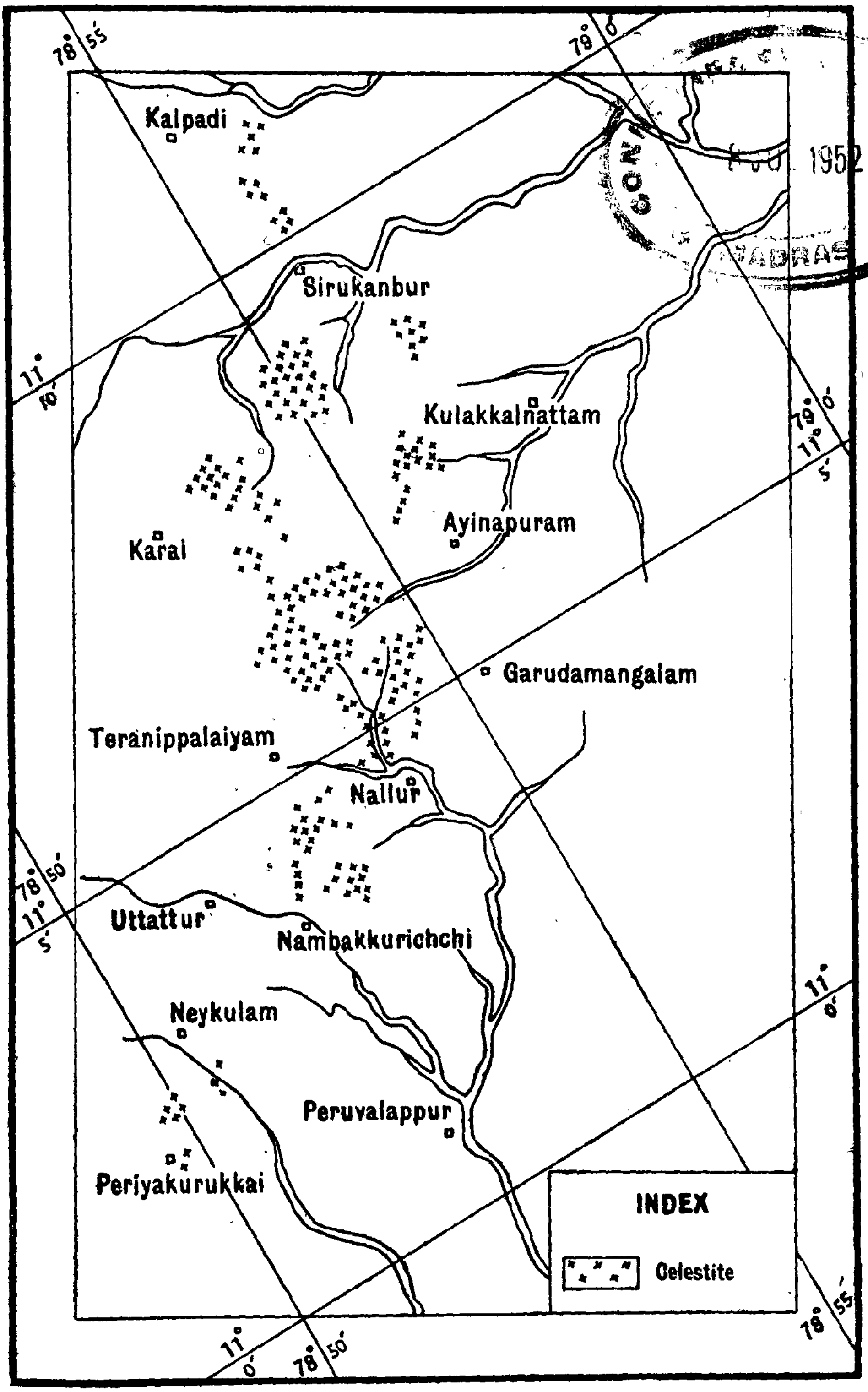

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MAP SHOWING OCCURRENCES OF CELESTITE IN THE TRICHINOPOLY DISTRICT, MADRAS.

Scale of Miles

Miles 2 1 0 2 4 Miles

Based upon Survey of India map 58I/16.

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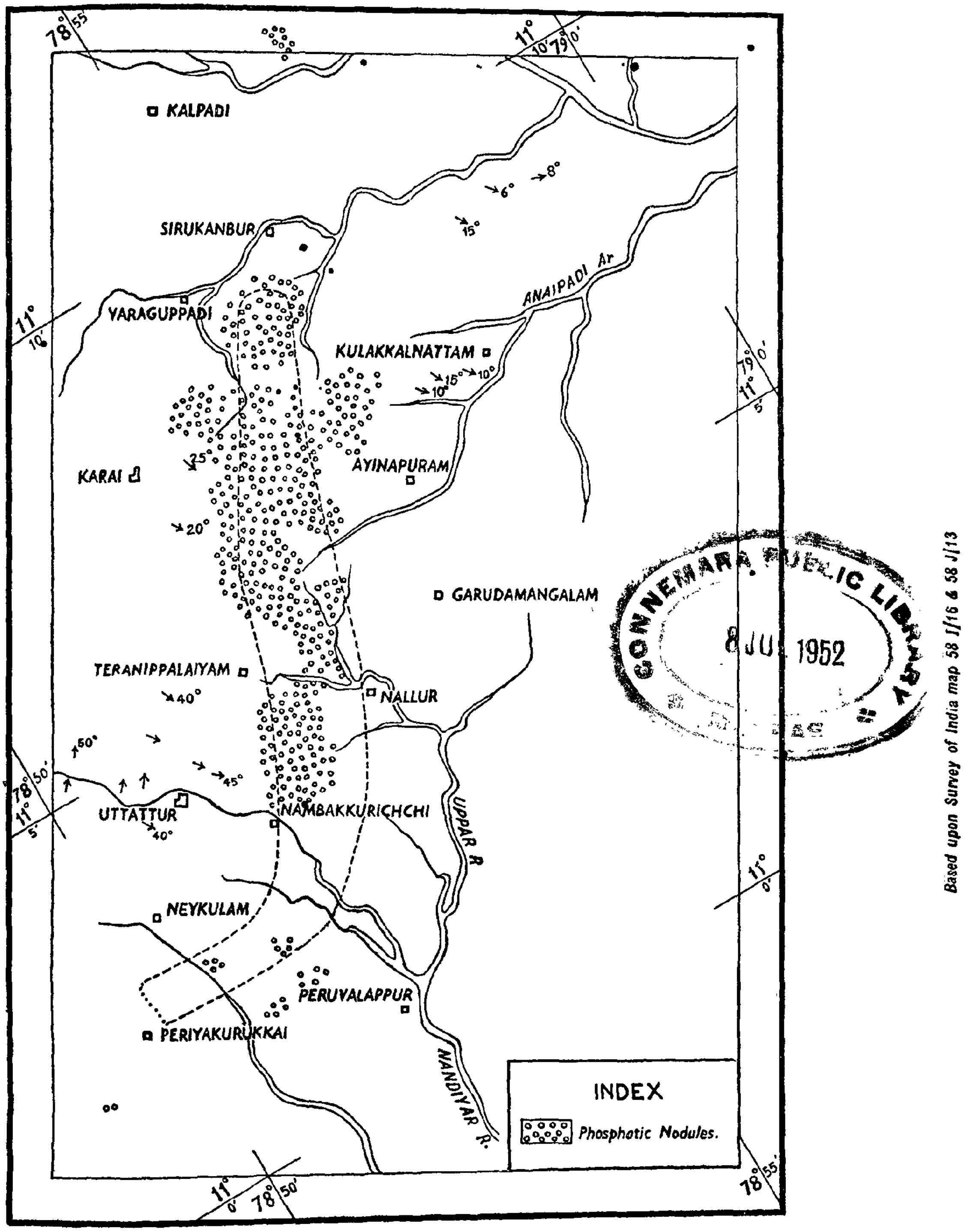

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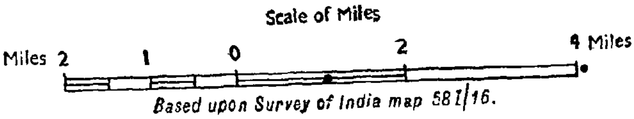

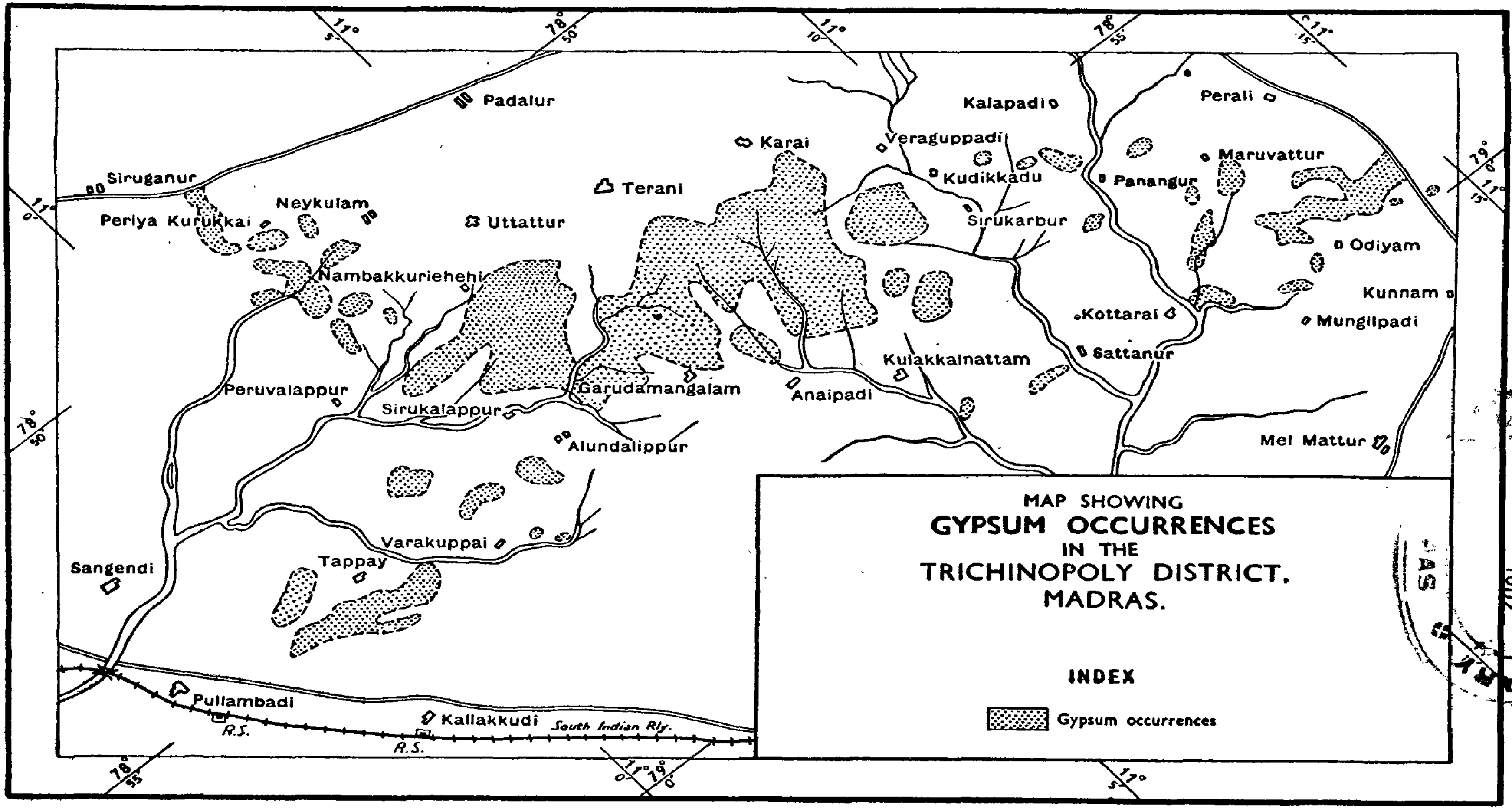

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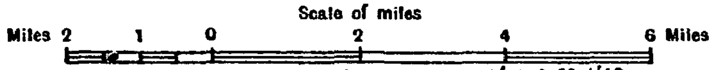

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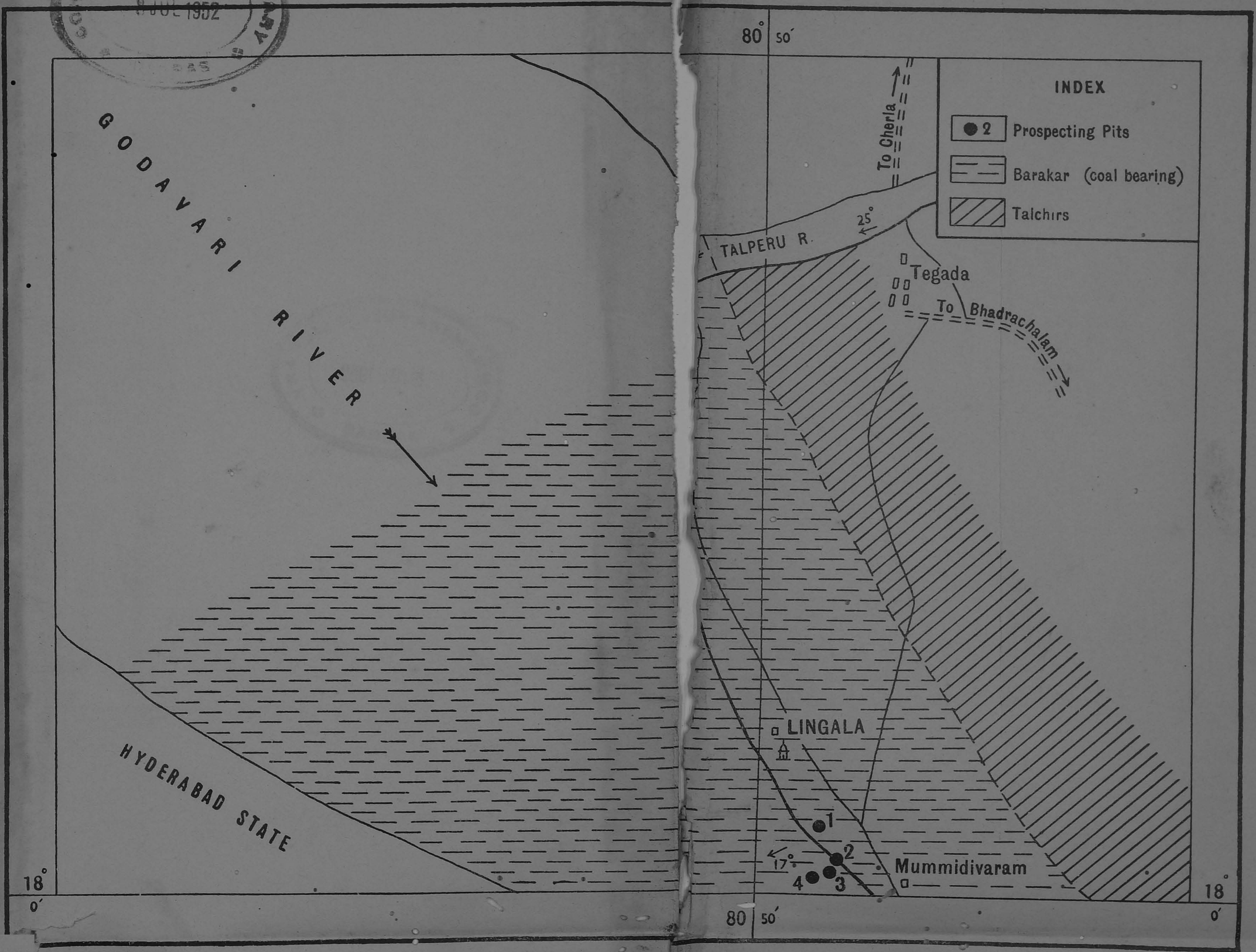

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MAP OF LINGALA FIELD

Scale

Furlongs 8 6 4 2 0 1 2 Miles

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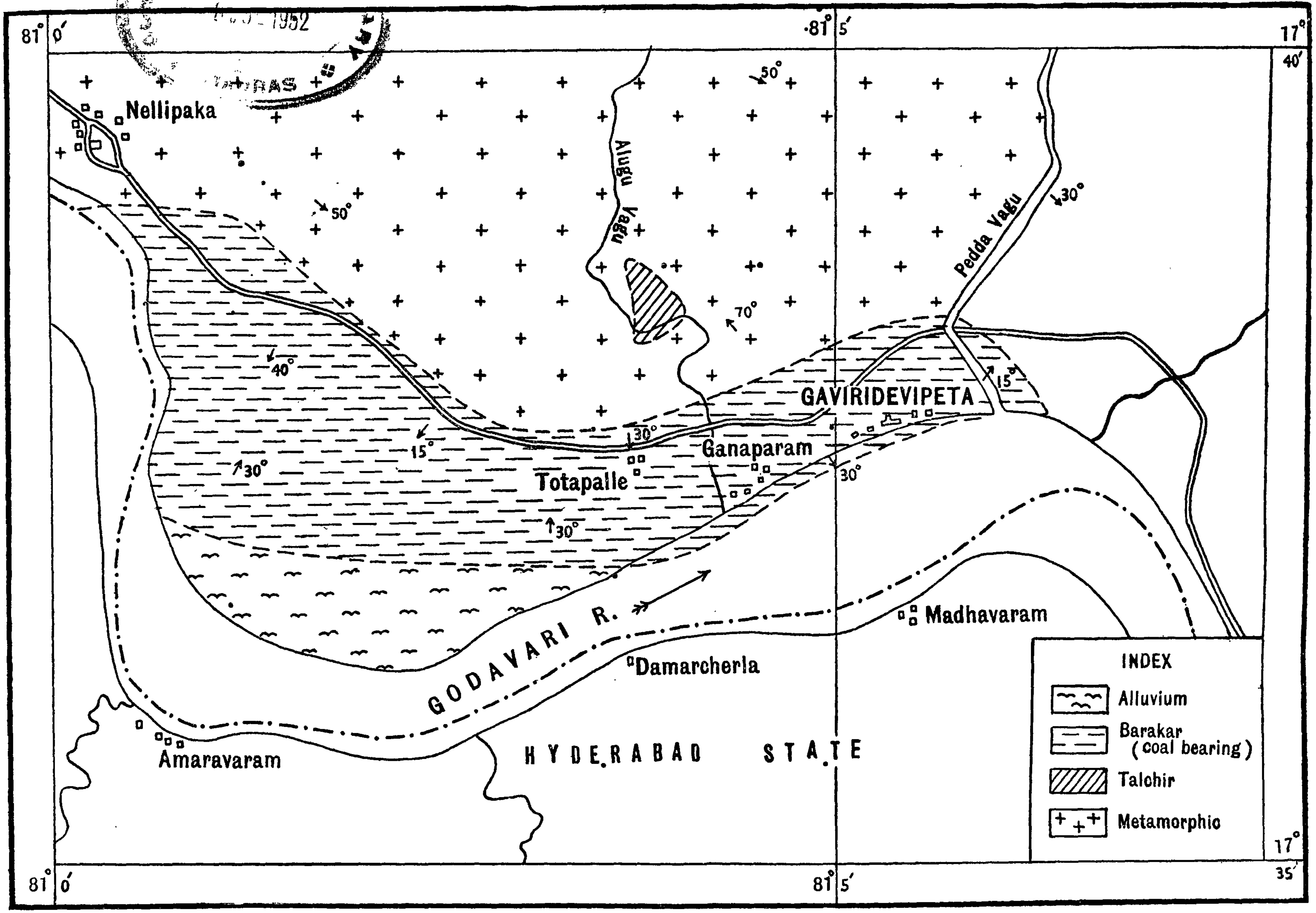

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GAVIRIDEVIPETA COALFIELD

SCALE OF MILES

Furlongs 8 6 4 2 0 1 2 3 Miles

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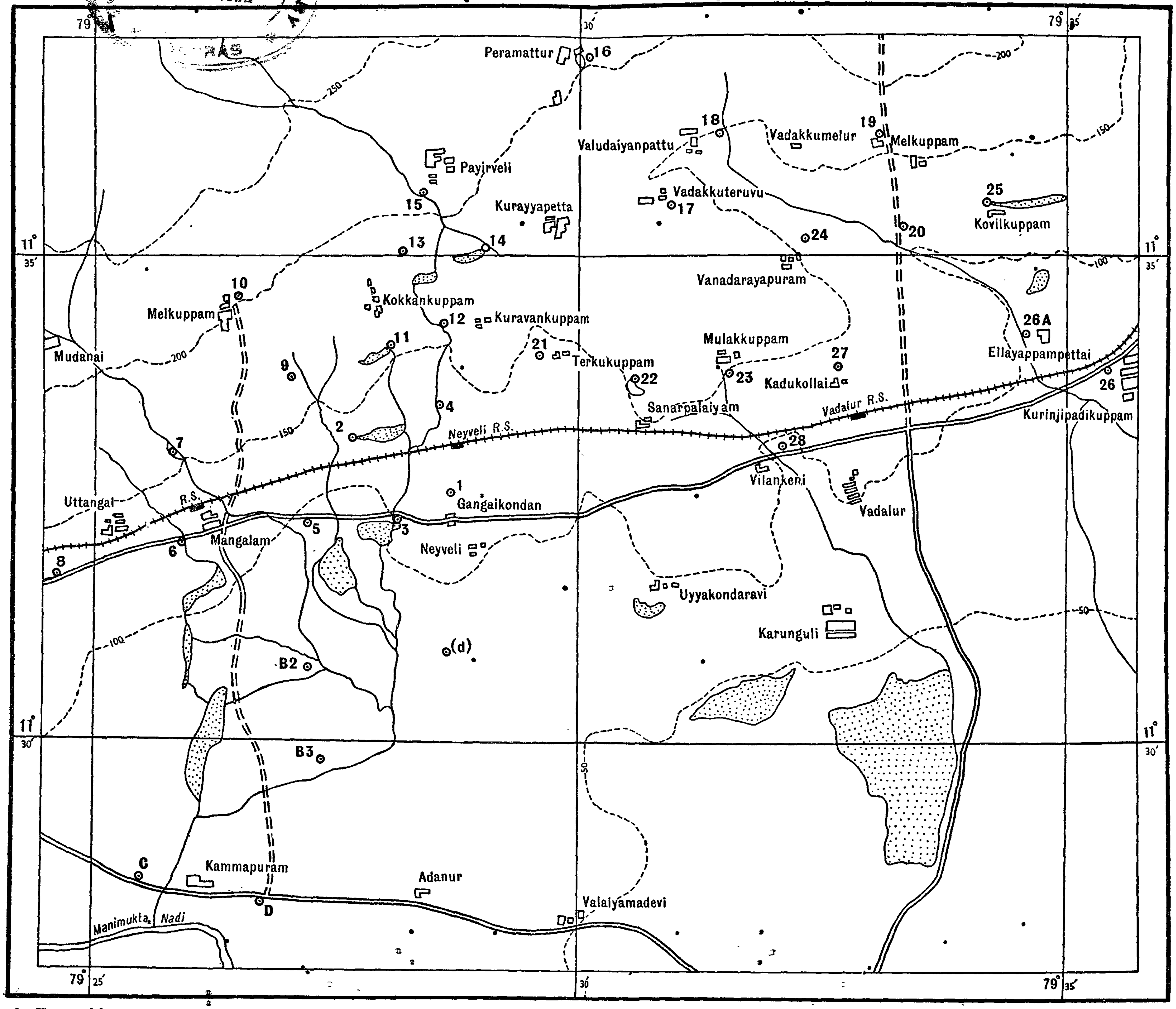

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NEYVELI LIGNITE FIELD, SOUTH ARCOT DISTRICT. SHOWING LOCATION OF BOREHOLES

Scale of Miles

Furlongs 8 6 4 2 0 1 2 Miles

Based upon Survey of India map 58M/6,7,10 & 11.

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